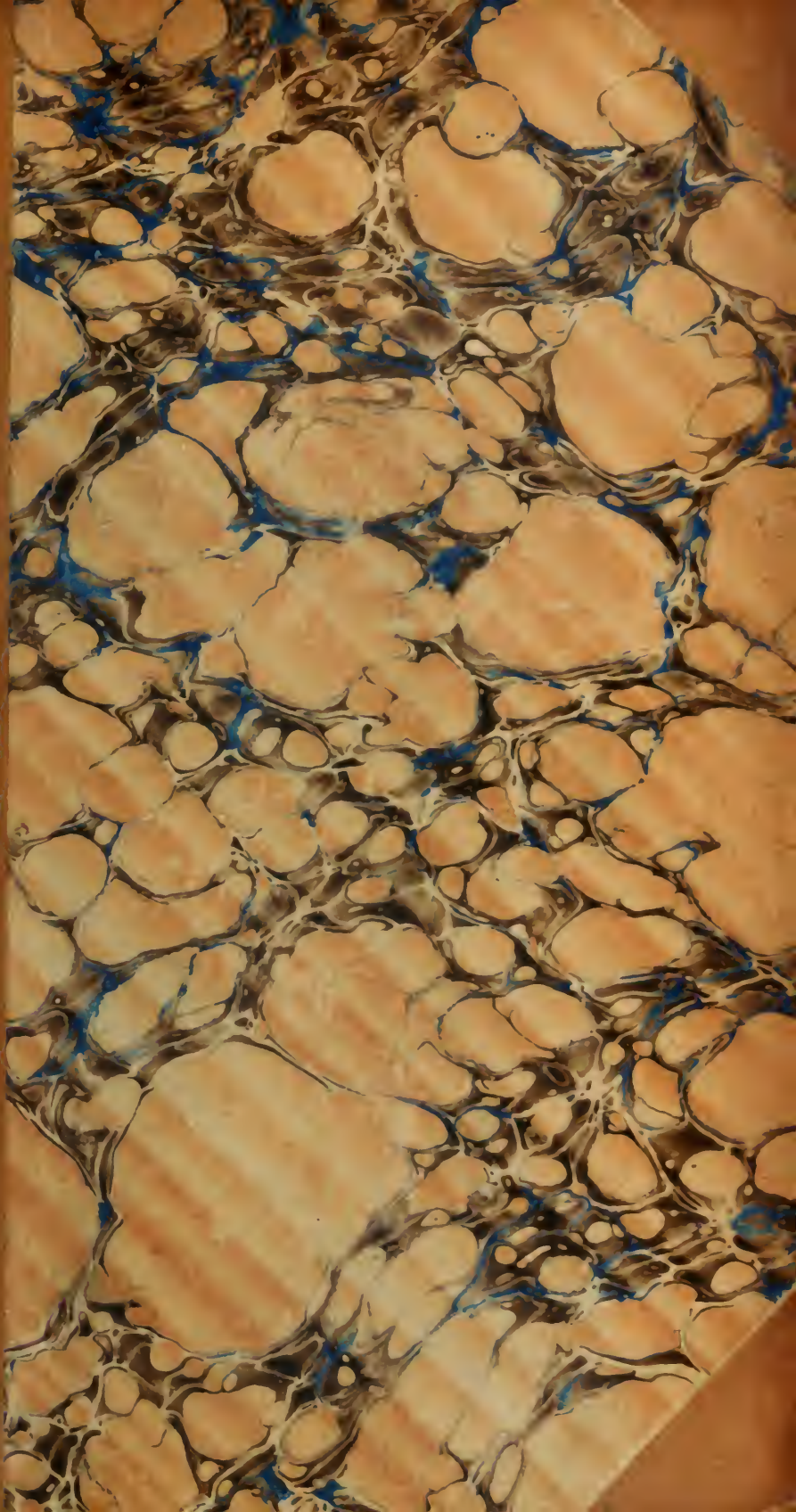
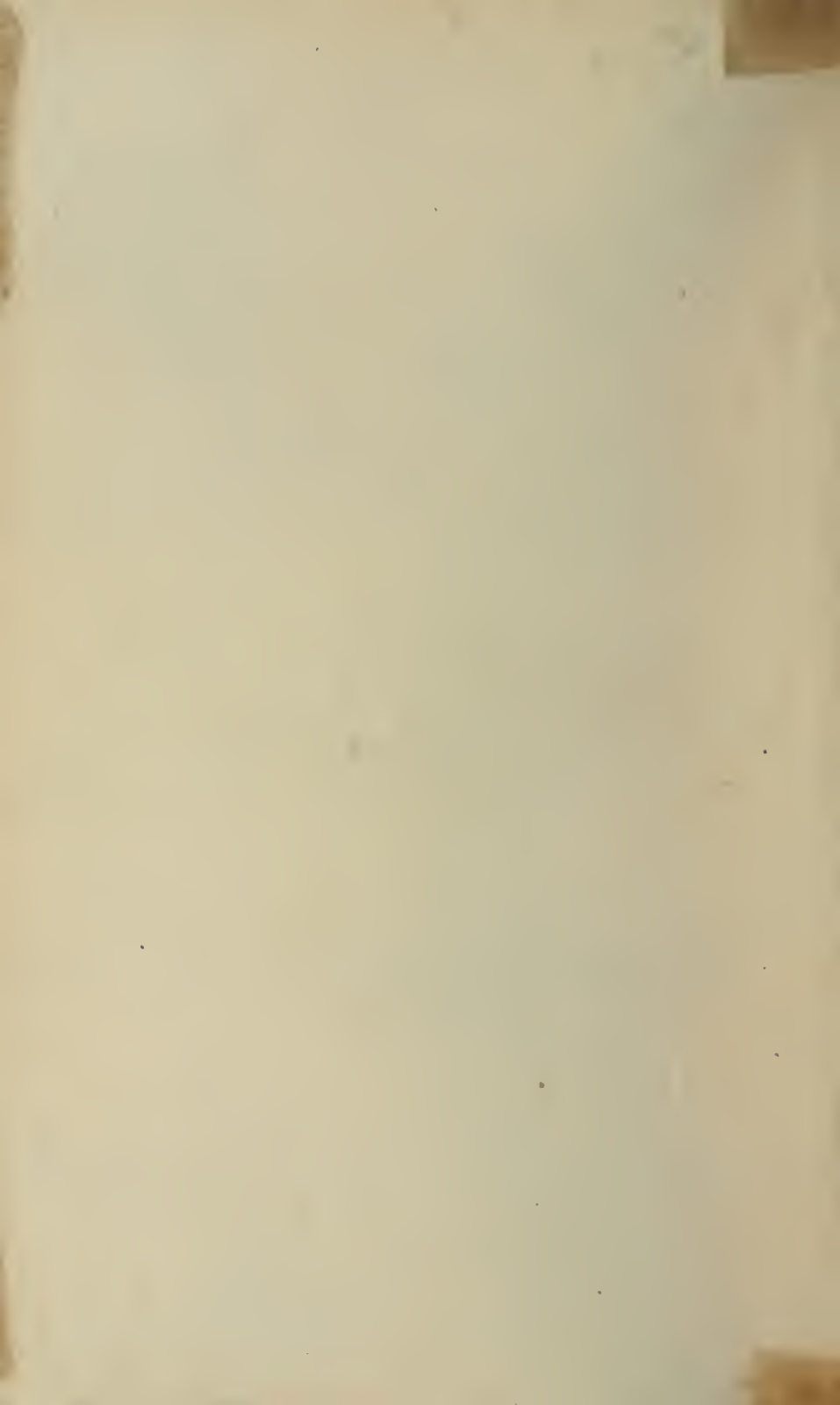






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POWER TRANSMITTING MECHANISM.*

ON THE STRENGTH OF THE TEETH OF WHEELS.

BY J. H. COOPER.

The object of this paper is to correctly report the existing rules and formulæ for the strength of the teeth of wheels, to give all definite statements of the experiments upon which such rules are founded, as fully as the limited records at command permit, and, finally, by the use of like dimensions, to work out an example by each of the several formulæ for the practical end. The example chosen for this purpose is considered to be a fair one by several writers on this subject.

In order to present in each rule the same general form, which is adopted for ready reference, and at the same time to not affect the integrity of its purpose, the notation has been changed to the initial letter of the part specified, and written rules agreeably to the above have been converted into formulæ.

This method of presentation has been selected to show at a glance the precise elements of the wheel which enter into the make-up of the rule, and to give the result of each rule after complete working out of the conditions named.

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NOTATION.

The same letters refer to like parts in each formula.

Let p = pitch of teeth in inches.

t = thickness " "

l = length " "

f = face " "

L = length of teeth in feet.

d'' = diameter of wheels in inches.

d = " " in feet.

n = Rpm. = rev. per min.

v = Fps. = velocity of pitch line in feet per second.

v' = Fpm. = " " " in feet per minute.

H = horse-power transmitted.

S = stress on teeth in lbs.

Each formula is solved by the introduction of the following elements: the results are placed in the 4th column and show plainly the values of H and S according to each authority.

$p=3''$; $t=1.38''$; $l=2.1''$; $f=7.5''$; $d=5'$; $n=60$; $v=15.708'$;
 $t = .46$ p; $l = .7$ p.

TABLE I.

From Bourne on "Steam Engine."	No.	Authority.	Formula.	Horse-power.
	1	Boulton and Watt,	$H = \frac{p^2 \times f \times d \times n}{306}$	66.17
	2	Carmichael, 1814, copied by Grier and Templeton,	$H = \frac{t^2 \times f \times v}{2.27 l}$	47.06
	3	Stripe,	$H = \frac{t^2 \times d'' \times n}{100}$	68.56
	4	Tredgold,	$H = \frac{p^2 \times v}{1.75}$	80.78
	5	Farey, 1827,	$H = \frac{p^2 \times f \times d \times n}{240}$	84.37
	6	Hick,	$H = \frac{p^2 \times f \times v}{16}$	66.27
	7	Robertson, 1814,	$H = \frac{t^2 \times f \times v}{4}$	56.09
	8	Glasgow Practical Mech'e,	$H = \frac{p^2 \times v}{2.5}$	56.55
	9	" " "	$H = \sqrt{\frac{p^2 \times n^2 \times f}{4.5}}$	73.49

No.	Authority.	Formula.	Horse-power.
10	Buchanan,	$H = r \left(\frac{t}{.75} \right)^2$	53.18
11	Fairbairn,	$H = r \left(\frac{t}{.587} \right)^2$	86.75
12	"	$H = \frac{t^2 r}{.344}$	86.96
13	Box,	$H = 1 \cdot dn \times p^2 f \cdot 043$	50.27
14	Molesworth, 1875.	$H = .06 p^2 r f$	63.62
15	D. K. Clarke,	$H = \frac{p^2 d n}{58.3}$	46.31
16	Nystrom,	$H = r \left(\frac{t}{.663} \right)^2$	67.96
17	" 1854,	$H = .614 p^2 r$	86.8
18	" "	$H = 2.9 t^2 r$	86.75
19	" 1875,	$H = \frac{t f r}{.55}$	295.59
20	" "	$H = \frac{p f r}{1.2}$	294.525
21	Jones and Laughlins,	$H = \frac{p d'' f n}{550}$	147.27
22	Haswell,	$H = r t^2 5.45$	163.
23	"	$H = r \left(\frac{t}{.465} \right)^2$	138.23
24	Engineer and Mach. Ass't,	$H = .4 p^2 r$	56.55

TABLE II.

No	Authority.	Formula.	Safe stress in lbs.
1	Tredgold,	$S = 138 p f$	3,105.
2	Engineer and Mach. Asst.,	$S = \left(\frac{P}{.0517} \right)^2$	3,364.
3	Morin,	$S = \left(\frac{t}{.025} \right)^2$	3,047.
4	Tredgold, quoted by Rankine,	$S = 1500 t^2$	2,856.6
5	Rankine, 1869,	$S = 160 p f$	3,600.
6	Engineer and Mach. Asst.	$S = 1600 t^2$	3,047.
7	" " "	$S = \left(\frac{t}{.025} \right)^2$	3,047.

No.	Authority.	Formula.	Safe stress in lbs.
8	J. G. Lawrie,	$S = 510 p f$	11,475.
9	W. C. Unwin,	$S = 200 p f$	4,500.
10	F. Campin,	$S = \frac{1333\frac{1}{3} f t^2}{l}$	9,068.6
11	Box,	$S = \frac{t^2 f 600}{l}$	4,081.
12	Imp. Journal,	$S = 1576 t^2$	3,001.3
13	D. K. Clarke,	$S = 900 t^2$	1,713.96
14	"	$S = 180 p^2$	1,620.
15	Haswell, 1860,	$S = 135 p f$	3,037.5
16	" 1868,	$S = \frac{720 f t^2}{l}$	4,897.
17	Nystrom, 1854,	$S = 1600 t^2$	3,047.
18	" "	$S = 300 f t$	3,105.
19	" 1875,	$S = 1000 f t$	10,350.
20	" "	$S = 460 p f$	10,350.
21	"	$S = \frac{150 f t^2}{L}$	12,242.57
22	Haswell,	$S = 3000 t^2$	5,713.2
23	"	$S = \frac{V f t^2}{L}$	4,897.
24	J. Christie, 1877,	$S = 462 p f$	10,395.

NOTES ON TABLE I.

Formula 2. "The rule given by this authority is $\frac{t^2 \times f}{l}$ at 2.27 ft. per second; but we have altered it to be applicable to all velocities: $p = 2.1 t$; $l = 1.2 t$; $f = 4 t$."

Formula 6. "This rule is $\frac{p^2 \times f}{4}$ at 4 feet per second. We have altered it for all velocities: $l = \frac{7}{12} p$."

Formula 7. "This is $t^2 \times f$ at 4 feet per second. We have made it for all velocities: $p = 2.1 t$; $f = 4 t$."

Formula 8. "In this rule $p = 2.1 t$; $f = 2 l$ as available for strength."

Formula 9. "The breadth of teeth suitable for wear is $f = 2 \frac{H}{n}$;

or, according to Rennie, $f = 1.8 \frac{H}{n}$; if we incorporate the latter element with formula 8, we get formula 9."

Formula 10. Buchanan's rule for the thickness of cast iron teeth for wheels, see his "Practical Essay on Mill Work." John Weale, London, 1841, p. 109. "Find the number of horses which are equivalent to the power of the first mover of the train of machinery, and divide that number by the velocity, in feet per second, of the pitch line of the pinion or wheel. Extract the square root of the quotient, and three-fourths of this root will be the least thickness of the tooth for the wheel or pinion, in inches."

Formula 11. From Fairbairn's "Mills and Mill Work," 1863, p. 45, deduced from Tredgold's rules. Insert .821 for brass, .891 for wood.

Formula 12. From Fairbairn's "Mills and Mill Work," 1863, p. 46, deduced from Tredgold. Insert .674 for brass, .795 for wood.

Formula 13. Empirical rule by Box in his "Mill Gearing," p. 26, for ordinary wheels of cast iron in use. Insert .05 in formula for wooden teeth. For bevel wheels p should represent the *mean* pitch, not that usually given, which is the maximum measured on the greatest circle of the working cone.

Formula 14. "Molesworth's Pocket Book of Engineering Formulae. London, 1875, p. 200." $t = .45 p$; $l = .75 p$; height of tooth above pitch line, $.33 p$; $f = 2 p$ in small pitches and $3 p$ in large.

Formula 15. "D. K. Clarke's Tables and Rules, 1877, p. 738." Insert 33.9 for gun metal (copper and tin); 20.2 for wrought iron; 13.1 for steel.

Formula 16. Nystrom's rule, quoted by Haswell, 1867, p. 516.

Formulae 17 and 18. Nystrom's rules, corrected from his 1854 edition of his Pocket Book.

Formulae 19 and 20. Nystrom, 1875, p. 297. The face, f , is generally made $= 2.5 p$; $\therefore f = 5.435 t$; $t = .46 p$, and $p = 2.1739 t$.

Formula 21. Jones and Laughlins' "Useful Information for Engineers," p. 51. Height of the tooth $= .32 p$; depth of the tooth $= .38 p$; $t = .48 p$ for cast wheels; $t = .5 p$ when cut.

Formula 22. Haswell, 1860, p. 163. Rule "To find the Horses' Power of a Tooth, the Dimensions and Velocity being given."

"Thickness² $\times$ 3000 = pressure" (a)

"Pressure $\times$ velocity in feet per minute
 $\frac{\quad}{33000}$ = H. P."

"Thickness $\times$ 2.1277 + = the Pitch."

"Thickness $\times$ 1.5384 + = the Length."

"The Breadth should be 2.5 times the Pitch."

"The Thickness should be .47 of the Pitch."

The velocity here is given in feet per minute, whence inserting velocity in Fps and the elements of the pressure (a), we will have:

$$H = v^2 5.45$$

Formula 23. Haswell's (1867, p. 516) Rule for "the Depth of a Tooth, when the Horses' Power alone is given."

"Extract the square root of the quotient of the horses' power, divided by the velocity of the teeth in feet per second, and multiply it by .465."

Formula 24. "Engineer and Machinist's Assistant," p. 96. With a pitch of 3 inches, $t = 1.4$ inches; $l = 2.1$ inches; least $f = 4.2$ inches.

NOTES ON TABLE II.

Formula 1. Tredgold, giving results near those of his table in his treatise on the steam engine. John Weale, London, 1838.

Formulae 2 and 6. "Engineer and Machinist's Assistant," Glasgow, 1856, p. 92. "Thus, for cast iron teeth this rule gives $p = .0517 \sqrt{S}$, and for a pressure of 15,000 lbs. we have $\sqrt{S} = \sqrt{15000} = 122.5$ and $.0517 \times 122.5 = 6.333$ inches. The wheel from which this example is taken has been several years in action, and has an actual pitch of 6 inches, and the mean pressure at the pitch circle is 14,786 lbs.

Clearance of teeth $\frac{1}{15}$ of the pitch; for brass teeth use .0723, for wood .0785.

Formulae 4 and 5. Rankine in his "Tables and Rules," p. 233, gives a rule "to find the *least thickness* suitable for the teeth of a wheel. Divide the pressure in lbs. to be transmitted by 1500, and extract the square root of the quotient for the thickness on the pitch circle in inches."

"To find the *least pitch*, multiply the least thickness on the pitch circle by 2.2."

"To find the *least breadth*, divide the pressure in lbs. to be transmitted by 160, and by the pitch in inches."

In his "Mechanical Text Book," Rankine adds: "The *thickness* of a tooth is fixed according to the principles of strength, and the *breadth* is so adjusted that when multiplied by the pitch the product shall contain *one square inch* for each 160 lbs. of force transmitted by the teeth."

Formula 7. Can be loaded to half more and yet be within the elastic limit. Insert .035 for brass and .038 for wood. S in this rule is $\frac{1}{10}$ the breaking weight.

Formula 9. W. C. Unwin, 1877. $\frac{1}{10}$ of the stress, by this rule, should be put on wooden teeth. This formula, deduced from table on page 184 of his "Elements of Machine Design," D. Appleton & Co., New York, 1877. For wheels of 3 inch pitch, when the load is quietly laid on, $S = 5625$; when shock is moderate, $S = 3600$, and when shock is excessive $S = 2493$ lbs. for safety.

Formula 11. Box on the absolute strength of the teeth of wheels for cranes and other like purposes. The stress being put on the teeth at very low velocities, and calculated at $\frac{1}{10}$ of the stress which would break the teeth. Box estimates shrouded teeth of same pitch and face at 40 to 50 per cent. stronger than those not shrouded, and wooden teeth of *Hornbeam*, which has a tensile strength of $\frac{3}{10}$ that of cast iron, at $\frac{1}{2\frac{1}{3}}$ the transverse strength of iron teeth.

Formula 13. D. K. Clarke. Insert 1600 for gun metal, 2600 for wrought iron, 2900 for steel.

Formula 14. D. K. Clarke, 1877. Equal to $\frac{1}{10}$ the breaking stress. For cast iron 180 to 310, for gun metal (copper and tin) 310, for wrought iron 520, for steel 800.

D. K. Clarke's rules for the "ultimate transverse strength of the teeth of ordinary cast iron wheels" are based upon an assumed line of rupture, the diagonal of a square whose side is the length of the tooth, which is in fact the line of least theoretic resistance with the stress at the corner, although not the line of actual fracture, according to which for strength alone it is needless to make the face of wheels more than twice the length of the tooth. Quoting Fairbairn, Clarke gives to wooden teeth a thickness equal to $\frac{2}{3}$ of the pitch, whereas the iron teeth

have $\frac{2}{5}$, no allowance being made to gain clearance, for when properly shaped the teeth will all work closely into and out of their interspaces.

Formulae 17, 18, 19, 20. Mr. Nystrom's earlier rules are evidently of English origin, and as good as they, having been derived from $S = 1600 f^2$, but his later formulae which with gear having strongly rooted teeth of good material, with well fitted and mounted wheels, shafts and bearings, are certainly in every way capable of transmitting the power assigned to them, and then he assures us he has deduced them from gears in actual use.

Formulae 17 and 18. Nystrom, 1854. Abrasion included in these formulae and $f = 2.5.p$.

Formula 19. Nystrom, 1875. This rule provides for carrying the load always on two teeth, and is thus equivalent to $\frac{1}{16}$ the breaking stress.

Formulae 19, 20 and 21. Nystrom, 1877. "The coefficient I have given for strain on teeth is only $\frac{1}{8}$ of the breaking strain, although it is about three times the old rule. Thus:

$$\text{Safety strain} = S = \frac{150 f t^2}{L} = \frac{150 \times 7.5 \times 1.9044}{.175} = 12242.57$$

If you count two teeth in gear at a time, the safety is $\frac{1}{16}$ of breaking strain."

Formula 22. Haswell. $f = 2.5 p$; $t = 2.127 p = 1.5384 l$.

Formula 23. Haswell's (1867, p. 515) Rule for "the Dimensions of a Tooth to Resist a given Stress."

"Multiply the extreme pressure at the pitch line of the wheel by the length of the tooth in the decimal of a foot; divide the product by the *Value* of the material of the tooth; the quotient will give the product of the breadth and square of the depth."

"The *Value* of cast iron for this or like purposes may be taken at from 45 to 65. In this case it is taken at 60."

Formula 24. James Christie, Philadelphia, 1877. This rule represents $\frac{1}{8}$ the breaking stress. See his discussion of the subject.

Having presented most of the rules on the strength of the teeth of wheels to be found in the existing engineering treatises published at home and abroad, it will help to an understanding of their essential elements by giving in detail some of the experiments made from time to time upon the material of which most wheels are made.

It is certainly necessary to know the strain that breaks a piece of projecting cast iron of given size and shape, when the stress is laid on quietly, as well as when it is driven on with considerable velocity. It is also important to know the fractional part of the rupturing weight or stress which may be repeatedly laid on with perfect safety, to insure the continuance of cohesion under the usual conditions of working.

Upon these essential features of each case the criteria of almost every engineer's guide book is silent. To stand safely, therefore, on the certainties of knowledge, one must have definite and accurate means of ascertaining the mechanical properties of the materials upon which dependence is to be placed, and in the line of this branch of the inquiry we present the data from which Boulton and Watt made their rule for the strength of the teeth of wheels.

"A bar of cast iron one inch square and twelve inches long bears 600 lbs. before it breaks; one inch long will bear 7200 lbs., and $\frac{1}{16}$ of this = 480 lbs., which is the load that should be put on a wheel."

Prior to this test we have the record of John Banks, in 1803, on 1" $\square$ cast iron 3' between supports giving, in 10 experiments, an average of 844 lbs., ranging from 730 to 972 lbs. at the middle of the bar, producing rupture.

To find the pressure that breaks 1" $\square$ section at 1" distance from the support we have $\frac{844 \times 36}{4} = 7596$ lbs.

Rondelet's six trials in Paris in 1814 averaged 6012 lbs., and later, Tredgold's five trials averaged 7416 lbs. on cast iron bars of same section and length.

In Pole's work on "Iron," 1872, page 90, occurs the following: "There is an exceedingly simple rough datum for the transverse strength of cast iron which is well worth committing to memory. It is, that a bar 1 inch square and 1 foot long will break with a load of about 1 ton hung on the middle."

In this we have $\frac{2240 \times 12}{4} = 6720$ lbs. on 1" $\square$ by 1" long.

Barlow says: "Cast iron has its elasticity destroyed with about one-third the weight that will produce rupture; it ought not therefore to be loaded in permanent constructions to more than this amount."

Mr. F. Campin, C. E., in the *Artizan*, says: "It is found that a cantilever of cast iron 1' long, 1" wide and 1" thick breaks under an

extreme load of 8000 lbs. To find the breaking weight of any given cast iron cantilever loaded at the end, multiply the breadth in inches by the square of the thickness in inches, the product by 8000, and divide by the length in inches. In practice, it is usual to make the working stress $\frac{1}{8}$ of the breaking weight, then the formula for safe load would be: $S = \frac{8000bt^2}{6l}$; or, to put it in the same form as the others,

see formula 10 in table II.

We can therefore rely upon Boulton and Watt's data, *i. e.*, 7200 lbs. breaks a bar of cast iron 1" $\square$ by 1" long; $\frac{7200}{3} = 2400$ lbs., the elastic limit, which, if exceeded, would end in rupture, and $\frac{2400}{5} = 480 =$ the safe load.

The question of how many pounds pressure upon the point of the tooth, whose elements are given above, will be necessary to break it, may now be considered.

$$\text{For this we have } \frac{7200 \times 7.5 \times 1.38^2}{2.1} = 48970$$

and $\frac{1}{15}$ of this is 3265 lbs., which is near the average of the rules tabulated in this article.

Mr. J. Anderson, "On the Strength of Materials and Structures," D. Appleton & Co., New York, 1872, says: "A cast iron bar of good quality, 1 inch long and 1 inch square, loaded at the end, would break with about 6000 lbs."

"The tooth of a cog wheel is to be considered as in similar conditions to such a bar, that is, in the condition of a beam fixed at one end and loaded at the other, and its resistance to fracture is proportional to its length or projection inversely, to its breadth or face directly, and to the square of its depth or thickness.

Tests of American cast iron are given herewith for comparison, reference being had to "Reports of Experiments on the Strength and other properties of Metals for Cannon," published by officers of the Ordnance Department, U. S. A., 1856. We find as the result of 18 tests of transverse strains, made by Maj. Wm. Wade upon various samples of American irons, the following results after the second and third fusions, that is, once and twice melted in the foundry furnace:

Maximum unit of strength,	.	.	11,046 lbs.
Minimum " "	.	.	6,207 "
Average " "	(18 tests)		7,969 "

These trials were made with bars each 24" long (and averaging 2 ins. square), supported at both ends, 20" between supports. "The 'Unit of Strength' represents the weight, in pounds, required to break a bar one inch square, supported at one end, the weight being applied at a distance of one inch from the point of support. For square bars it is determined by the formula $\frac{lw}{4bd^2} = S = \text{the unit of strength};$

l being the length between the supports, w the breaking weight, b the breadth of the bar and d the depth.

From John Farey's *Treatise on the steam engine*, London, 1827, p. 628, we extract the following particulars of Mr. Loyd's "strong cranes." "The largest size is adapted to lift twenty tons weight: the chain is made of iron, 1 $\frac{1}{4}$ " diameter, and winds round a grooved barrel 22" diameter. The axis of this barrel is made of wrought iron 4" square; the gudgeon at one end is 3" diameter, and 3 $\frac{1}{2}$ " long; the neck at the other end is 4 $\frac{3}{4}$ " diameter, 3 $\frac{1}{2}$ " long. The barrel is turned round by this neck to wind up the chain; and the cast iron cog-wheel, which is fixed on the extreme end of the axis, beyond the neck to turn it round, is 6' diameter with 152 teeth, which are 1.49" pitch, and 3 $\frac{1}{4}$ " broad.

"The teeth are rounded at the ends nearly to a semicircle, and the spaces between the teeth are also hollowed out nearly to a semicircle: this form gives the teeth very great strength at the roots, where they join to the rim of the wheel. The wheel is turned by a cast iron pinion of 17 teeth, which are of a corresponding form to those of the wheel, but the pinion has a circular rim, or flange, at each end of the teeth, which greatly strengthens them, being cast in one piece with the teeth. With this form of teeth, only one pair of the teeth of the wheel and pinion are in actual contact at the same time, so that one tooth bears all the strain."

Calculation for the teeth:

$$\frac{44800 \times 22}{72} = 13689 = \text{pressure upon the teeth.}$$

$$\text{Then } \frac{13689}{1.49^2 \times 3.25} = 1898 \text{ lbs. is the propor-}$$

tionate pressure for cast iron teeth of 1" pitch and 1" face. This is $17\frac{1}{4}$ times our assumed standard of 110 lbs."

"These cranes are always proved by lifting the full weight that they are intended to bear. * * * They rarely break wheels, but sometimes twist, yet never break the necks of the drum shafts."

A curious application of a rule for the teeth of mill wheels occurs in "Farey's" Treatise, p. 627, which is quoted in full.

"The great wheel of a very excellent pocket watch, made by Mr. Pennington, is .764 of an inch diameter, with 60 teeth, which are .04 of an inch pitch and .04 of an inch broad. The strength of these teeth is therefore $.04^2 \times .04 = .0064$. To find the force which these teeth transmit, a wheel was affixed to the watch key, and a sufficient weight applied by a silk thread to the circumference of the wheel to wind up the watch.

"It appeared that the constant pressure upon the teeth is .83 of a pound, which $\div .0064$ strength of the teeth, gives 130 lbs. for the proportionate strength of teeth, one inch pitch and one inch broad, instead of 110.

"This watch has been in use for ten years past. The wheel is made of fine yellow brass, hammered very hard; it is gilt, but the gilding is not yet worn off the teeth."

The 110 lbs. referred to in quotation from Farey represent a *unit of measurement*; it is the pressure that may constantly be applied to the teeth with perfect safety, being from $\frac{1}{10}$ to $\frac{1}{15}$ of the breaking strength of a wheel one foot pitch diameter and teeth of one inch pitch and one inch face.

A correspondent of the *Engineer* says: "I herewith send you a rule for the strength of the teeth of wheels. As an example, 3" pitch is usually taken by all who have written on the subject, and at a velocity of 3 Fps.:

Tredgold gives it	.	15	H. P.
Eng. and Mach. Assistant gives it	.	14.5	"
Hick	"	10	"
Roberton	"	10	"
Carmichael	"	9.91	"
Farey	"	13.5	"
Buchanan	"	9.4	"

"These are all nearly correct, taking their data from wheels actually in use, and going at or near about three feet per second.

"I find for general use Tredgold's data and 'The Engineer's Assistant' the best, with the correction proper for the velocity.

"The breadth to be twice the pitch in all calculations for strength; any extra breadth is of no further use except for extending the bearing surface and lessening the wear. Practically, three times the pitch is the utmost limit. Fine pitch broad wheels are very apt to strip gear, especially when put on slight shafting which is the most deficient in lateral stiffness; sometimes whole teeth, and at others, portions, will break off diagonally with the radial line of tooth.

"Buchanan gives the best information on the teeth of wheels of any writer I have yet met with."

We add an original treatment of this subject by Mr. J. Christie, Engineer, Pencoyd Iron Works, Philadelphia:

"In most cases of gearing the question of least pitch is an important one, not only because it contributes to smoothness of running, but also because the linear tooth bearing increases with the lessening of the pitch.

"Many of the old English rules for strength of teeth are based upon the presumption that the teeth do not in action bear over the entire length of face, but only on the corners, in which case the line of rupture is a diagonal, rendering any increase of face of tooth beyond double the length of the tooth needless. This rule may be very well for gearing on weak or long shafts, or, worse still, when they overhang the bearing on weak shafts.

"To secure the advantages of face, the parts should be proportioned so as to preserve an even and continuous bearing of the teeth at all times.

"I have collected a number of cases, varying from 1" up to 4" pitch where the teeth are strained up to their utmost safe endurance, and feel convinced that the teeth of wheels can be treated in a rational way, as a beam rigidly supported at one end and loaded at the other; that is, loaded at the pitch line and all the load on one tooth. Further assuming that the length of beam or tooth is taken at $\frac{1}{10}$ of the pitch, a usual proportion of distance from root of tooth to pitch line, and also taking the *modulus of rupture* at 36,000, would give for the teeth of cast iron wheels a breaking strain of 3,700 lbs. for each inch of pitch and face, and advancing directly as the pitch and the face, although the transverse strength of rectangular sections increases as the square of the depth, yet in the case of the teeth of wheels there is

an inverse *decrement*, owing to the proportional increase of length of tooth.

“My rule would therefore be for cast iron teeth. $Pitch \times face \times 3700 =$ the ultimate breaking load in lbs. On account of the imperfect elasticity of cast iron, the working load should never exceed $\frac{1}{4}$ of the breaking strain and then under the most favorable conditions, such as well-fitted gear, rigidly supported, running at moderate speed and stress evenly distributed. For strains suddenly applied, the factor of safety should be 6, and when accompanied by severe shocks and sudden reversion of strains it should be 8. These are my conclusions, and I am prepared to sustain them by numerous examples, a few of which are given herewith; Spurwheels of $1\frac{1}{16}$ '' pitch and 4'' face on a crane, which for years have been subject to a tooth strain of 500 lbs. per inch of face; one of 4'' pitch and 12'' face, every day working under a strain of 25,000 lbs. and often 30,000 suddenly applied on the teeth; another of $2\frac{1}{4}$ '' pitch and 8'' face, subject to a frequent stress of 10,000 lbs., but which has had two breakages when the strain amounted to 13,500 lbs., suddenly applied, or 1700 lbs. (nearly) per inch of face.

“In estimating the moment of resistance of the tooth, I use the *modulus* suggested by Rankine, viz., 18 times the weight applied at the center necessary to break a bar 1'' square and 1'' between supports. In ordinary foundry iron this may be accepted as averaging 36,000 lbs. as stated, but as there is a wide range in the strength of cast iron or another material may be applied, a simple experiment will determine the proper *modulus*, and according as the result obtained will exceed or fall below 36,000, so will the proper coefficient in the formula vary from 3700.”

A Treatise on the Strength of Cast Iron Beams, by Wm. Turnbull, London, 1831, says: “Now it has been found, by very accurate experiments, that a bar of soft gray cast iron, 1 inch square and 34 inches between the supports, will bear a load of 300 lbs. in the middle of its length, while the elastic force remains perfect (see Tredgold on Cast Iron, Art. 45.)” Therefore, by substituting these numbers in the usual equation, and employing also the usual notation, we have:

$$l S = 850 b d^2$$

And when the beam is fixed at one end and loaded at the other we have:

$$l S = 212.5 b d^2$$

Putting l in inches, and dividing this by l we have :

$$S = \frac{2550 \ b \ d^2}{l}$$

If we now employ the notation and sizes of tooth given in statement above, in this last formula, and work it out in the same manner as those in the tables, we will have :

$$S = \frac{2550 \ f \ l^2}{l} = 16130 = \text{the safe stress within}$$

the limits of elasticity which may be repeatedly put on this tooth.

From Practical Rules for the Proportions of Cog Wheels and Shafting, by E. R. Walker, of Haigh Foundry, Wigan, Newcastle-under-Lyme, 1868, we select the following observations and rules, changing the notation :

"The results will be found to give a good average margin of strength with ordinary materials. The rules are based upon and have been tested by a large number of examples in actual operation, and they have been used in a considerable practice for some years."

"To find the extreme strain which the teeth of any wheel are capable of transmitting.

"Calling X = breaking load of tooth in lbs.

S = working " "

H = indicated horse-power.

R = radius of power.

p = pitch of teeth in inches.

f = face " "

d = diameter of wheel in inches.

n = Rpm.

v = speed of wheel rim in Fps.

m = 3 for very slow speed without shock.

= 4 when rim of wheel runs 3 Fps.

= 5 " " " 5 "

= 6 " " " 10 "

= 8 " " " 15 "

= 10 " " " 20 "

= 12 " " " 30 "

= 14 " " " 40 "

We have

$$X = 2000 \ p \ f$$

1

"The extreme or breaking load being found, and the speed given, to find the working load the wheel should bear

$$S = \frac{X}{m} \quad 2$$

"The working load and the speed being given, to find the extreme or breaking load

$$X = S m \quad 3$$

"Find m according to speed of gear and substitute in formula.

"To find the size of teeth to carry a given load in lbs.

$$\frac{X}{2000} = p.f \quad 4$$

"For bevel wheels take the mean pitch.

"Wheels of ordinary breadth are increased in strength if shrouded to the points of the cogs in the proportion of 5 to 3, and if shrouded to the pitch line in the proportion of 3 to 2.

"Wooden teeth, when the rims of the wheels run over 30 Fps., will drive as great a weight as cast iron of the same dimensions.

"To find the strain on the teeth of wheels on the shafts of engines, etc.

Rule for single engines or pairs of engines where the cranks are opposite to each other.

$$S = \frac{H \ 864}{v} \quad 5$$

Rule for pairs of engines where the cranks are fixed at right angles:

$$S = \frac{H \ 576}{v} \quad 6$$

Rule for water wheels or engines with uniform motion, or general machinery:

$$S = \frac{H \ 550}{v} \quad 7$$

Having found the working load or strain on cogs, proceed as before."

The amount of power that may be transmitted by gears after the pitch and face have been determined depends upon the speed of the load laid upon their teeth, which, apart from their size and shape, opens up new conditions of the problem, in which the effects of impact, vibration and centrifugal force due to high velocities must be considered as modifying somewhat both the pitch and the face.

Provision for these conditions can easily be made after the absolute strength of the teeth is determined and the elastic limit definitely known.

In practice, the efficiency of a wheel, even with ample pitch and face, will much depend upon the accuracy with which the parts hold their integrity of adjustment while working; for if the stress be laid on at the corners of the teeth, then the great advantage to be derived from a broad wheel is necessarily lost and might as well have not been provided.

It must be admitted that the shape of the tooth has something to do with its strength, and yet no allowance appears to have been made by the rules tabulated above for such distribution of the metal, the breaking strength being based upon the pitch or thickness of the teeth at the pitch line or circle, as if the thickness at the root of the tooth were the same in all cases as it is at the pitch line.

There are good reasons for taking account of this; according to one rule for shaping teeth the flanks should lie within radial planes, which of course would reduce the section of metal and weaken the teeth accordingly; to another rule the flanks should lie within parallel planes, which would comply fairly with the terms of those rules based on the tests of semi-beams of uniform square section throughout their length; to another rule, like Adcock's, for example, which makes the tooth decidedly pyramidal in form, with broad base, thereby greatly augmenting the strength of the tooth, in one case measuring 2 inches in a pitch of $2\frac{1}{2}$ inches, the comparative strength being for the parallel tooth $(2.5 \times .46)^2$, and for the pyramidal tooth 2^2 , or as 1.3225 : 4. All other rules provide for a spreading of the base of the tooth more or less between these extremes.

Even in well-shaped cut gears the root of each tooth has about $\frac{1}{8}$ additional metal more than the section at the pitch line, which would augment the strength of each tooth in the proportion of 1.2656 to 1.

So that while the rule based on the cog as a semi-beam may not be absolutely exact, the methods of calculation which do not include the root section of a tooth are very false.

"We know already that each material gives its own figures," quoting Weyrauch's words, and so also do the form of the tooth, the face as affected by the maintenance of adjustment to line and the uniformity of the velocity with which the load is transmitted through the teeth.

"The question is not about theoretical crotchets; and the names of the experienced practical men who have made these investigations should be sufficient warrant to those who are without experience. Yet if a new process is to be generally accepted, it must be theoretically sound, simple in application, and not contradictory to past experience."

THE AMERICAN RIVER PADDLE-WHEEL STEAMBOAT "MARY POWELL."

By CHIEF ENGINEER ISHERWOOD, U. S. Navy.

The *Mary Powell* is a typical example of the American paddle-wheel steamboat employed on the rivers of the Eastern portion of the United States. The hull is of wood, coppered, and is exceedingly light and shallow, depending for strength on an immense timber truss, or "hog-frame," erected on each side, and on a very deep keelson supporting, along the centre of the vessel, poles rising many feet above the roof of the saloon, from the tops of which sloping iron rods suspend the guards and ends of the hull. Of course, such a structure is suitable for smooth water only, and the elegant saloons erected upon it, of light joiner-work, afford spacious and convenient accommodations for the crowds of passengers carried.

The *Mary Powell* plies between New York City and Rondout, on the Hudson River, a distance of about 88 statute miles, making the round trip once a day during the summer "season" of each year, extending from about the middle of May to the middle of October. She carries passengers only, and her trips are made with great regularity, the times of starting and stopping varying but a few minutes from her schedule time. Her draught of water varies very slightly also, and her speed throughout the entire run may be taken, without sensible error, as absolutely uniform. The air resistance of the hull, must, at its high velocity, be considerable, as the top of the saloon is about 30 feet above the water, while the immersion of the hull, exclusive of the keel, is only 6 feet.

There is but one engine—placed in the centre of the vessel and bolted to its keelsons—and it is as typical as the hull, being a first-class specimen of the overhead-beam, or "walking-beam," kind, used exclusively on such steamboats, the beam being supported upon a lofty triangular gallows-frame of wood, very stiff and very light. The boilers, also, are peculiar to this style of steamboat. They are two in number, and placed outside of the hull upon the projecting guards behind the wheel-houses. This is the only place available for them, and as no more boiler space can be obtained than there is room for on

these guards, their rate of combustion has to be forced enormously by powerful fan-blowers to furnish sufficient steam for the large power required. Independently, too, of the limited space that can be devoted to the boilers, no greater weight of them can be allowed, even if more space was available. Anthracite of small nut size is burned, giving about one-sixth refuse. The vessel is coaled at Rondout, and carries just enough for one round trip. The paddle-wheels are of the usual radial kind. For river steamers carrying large numbers of passengers, no system, as a whole, has ever been devised equal to the paddle-wheel steamboats of the *Mary Powell* type.

The entire machinery with its appurtenances, including the water in the boilers, weighs about 210 tons; the coal embarked weighs about 30 tons; total in the engineer department, 240 tons, or 27.24 per centum of the vessel's displacement.

As there is no account to be found of the performance of such a vessel, my friend, the accomplished engineer, Mr. Theron Skeel, having occasion to make many trips in the *Mary Powell* during the summer of 1877, kept for me an accurate record of her running time between the cities of New York and Newburgh, 59 statute miles apart, together with the boiler pressure, vacuum, temperature of the feed-water, revolutions of the motive and blowing engines by counter, consumption of coal, etc., the coal being the amount purchased by the owner of the boat. He also took on each trip a large number of indicator diagrams from both ends of the cylinder, and made the other observations to be found in this article. The means from all these diagrams are given in the table of "performance."

During the round trip no water was blown from the boilers, and they remained entirely free of scale. There was no means of ascertaining the temperature of the gases of combustion in the chimney, but a piece of zinc suspended therein at the level of the top of the steam-drum melted promptly, showing the temperature to be above 750 degrees Fahrenheit. The temperature of the steam in the boiler, considered as saturated steam, would be 272 degrees Fahrenheit or more than 478 degrees Fahrenheit less than that of the gases of combustion passing through the steam-drum, which difference, taken in connection with the large extent of surface in the drum and upper part of the uptake, must have caused a considerable steam superheating. There was no means, however, of ascertaining this fact quantitatively, but it is believed that the superheating was sufficient to prevent any

steam condensation in the cylinder other than that due to the development of the total horses-power.

In the table of "performance" hereinafter given will be found grouped all the quantities observed and calculated. The power developed is that of the motive engine alone, exclusive of the power exerted by the blowing engines in driving the fans. Of the latter power no approximation can be made, as these engines used the steam greatly throttled but exhausted into the condenser. The weight of steam used, calculated from the indicator diagrams, is also exclusive of the weight consumed by the blowing engines; hence, if it be assumed that there was no condensation in the cylinder of the motive engine other than that due to the development of the total horses-power, then the cost of the horses-power in weight of steam consumed per hour can be ascertained. As the motive engine developed 1744·884 total horses-power, and as the indicator accounted for 38258·264 pounds of steam consumed per hour in its cylinder, there follows that the total horse-power was obtained for 21·93 pounds of steam consumed per hour.

The economic vaporization by the boilers can be ascertained, without error of practical importance, by assuming the weight of steam consumed by the blowing engine to be five per centum of the weight consumed by the motive engine. Adding this weight to the 38258·264 pounds of steam consumed by the motive engine per hour, there results 40171·177 pounds of steam evaporated per hour, from water at the temperature of 120 degrees Fahrenheit, and under the boiler pressure, by 6050 pounds of anthracite, or 6·64 pounds of water vaporized per pound of coal. This, of course, supposes no condensation in the motive cylinder, which was probably the fact, an inference warranted by the superheating of the steam, by the above cost of the total horse-power in pounds of steam consumed per hour and by the boilers' economic vaporization of 6·64 pounds of water per pound of coal consumed at the great rate of 39·286 pounds per square foot of grate surface per hour.

In computing the quantity of heat transformed into the total horse-power developed by the expanded steam, the mechanical equivalent of the heat required to raise the temperature of one pound of water from 32 to 33 degrees Fahrenheit is taken at $789\frac{1}{4}$ pounds, instead of Joule's equivalent of 772 pounds. The latter has long been known to be too small, and the former is the result of the experimental researches of Tresca and Laboulaye, endorsed by Regnault, Piobert, Combes, Bertrand and Morin. It should be universally adopted.

HULL.

Length on the load water-line from the forward edge of the rabbet of the stem to the after edge of the stern-post, ...	290 ft.
Extreme breadth on the load water-line, ...	34 ft.
Depth of hold from top of floor-timbers to under side of deck-plank, ...	9½ ft.
Depth from load water-line to lower edge of rabbet of keel, ...	6 ft.
Depth of keel below the lower edge of its rabbet, ...	6 in.
Area of the greatest immersed transverse section to load water-line, ...	198.5 sq. ft.
Displacement to load water-line	881 tons.
Ratio of the length to the breadth, ...	8.529
Ratio of the greatest immersed transverse section to its circumscribing parallelogram, ...	0.973
Ratio of the displacement to its circumscribing parallelo-pipedon, ...	0.520

ENGINE.

There is one overhead beam-engine with a wooden gallows-frame. The cylinder is vertical and has four balanced poppet-valves, two for admitting and two for exhausting the steam. The steam-valves function also as expansion valves by means of the mechanism known as Stevens' cut-off. The condensation of the steam is effected in a jet-condenser. The air-pump is vertical and single-acting. The cylinder is not steam-jacketed; its ends, its valve-chests and its side-pipes have no protecting covering, but its cylindrical portion and all the steam-piping connecting it with the boilers were well covered with asbestos felting.

During the performance hereinafter given, the steam-valves closed when 0.486 of the stroke of the piston was completed. There was but little exhaust lead, and the exhaust-valves closed and cushioned the steam when the piston was at 0.232 of its stroke from the end.

Number of cylinders, ...	1
Diameter of cylinder, ...	72 in.
Diameter of the piston-rod, ...	6¾ in.
Net area of the piston, exclusive of the piston-rod, ...	4053.62 sq. in.
Stroke of the piston, ...	12 ft.
Space displacement of the piston per stroke, ...	337.802 cub. ft.

Clearance of the piston, ...	1 $\frac{5}{8}$ in.
Capacity of steam-passage or nozzle at one end of cylinder, ...	8.488 cub. ft.
Aggregate space in clearance and steam-passage at one end of the cylinder, ...	12.300 cub. ft.
Least diameter of the seat of the upper disc of the steam-valve, ...	15 $\frac{3}{8}$ in.
Least diameter of the seat of the lower disc of the steam-valve, ...	14 $\frac{3}{4}$ in.
Least diameter of the seat of the upper disc of the exhaust-valve, ...	14 $\frac{3}{4}$ in.
Least diameter of the seat of the lower disc of the exhaust-valve, ...	15 $\frac{3}{8}$ in.
Area of steam-port, exclusive of valve-stems, ...	352 sq. in.
Diameter of air-pump (single-acting), ...	40 in.
Stroke of air-pump piston, ...	62 in.

BLOWING-ENGINES.

There are two blowing-engines—one for each boiler—employed in driving fan-blowers to produce an artificial draught. Each blowing-engine consists of one cylinder 12 inches in diameter, with 12 inches stroke of piston, geared by a belt to a Dimpfel blower 5 feet in diameter and 32 inches wide, which makes five revolutions to each double stroke of the steam-piston. The steam is cut off by lap on the steam-valve at three-fourths of the stroke of the piston from the commencement.

The delivering-nozzle of each fan-blower is connected by a rectangular conduit of sheet-iron with the closed front of the two ash-pits of its boiler, and they receive the air-blast beneath the grate-bars.

BOILERS.

There are two boilers, one placed on each guard of the vessel immediately behind the wheel-house. They have lower flues in direct continuation of the furnaces, with tubes returned above the flues and furnaces. The two boilers have no connection of any kind; they have separate chimneys, are fed separately with both water and air-blast and deliver their steam through separate pipes into one large steam-pipe. The external surfaces of the boilers are well covered with asbestos felting. The following is a description of each boiler:

The front portion of the shell is rectangular in plan, with flat sides.

and a semi-cylindrical top. The back portion is cylindrical, with its top a horizontal continuation of the top of the semi-cylinder of the front portion. The front portion is 10 feet 9 inches high, exclusive of water-pan beneath the grates, 8 feet $11\frac{1}{2}$ inches long and 11 feet wide. The back portion is 10 feet in diameter and 16 feet 1 inch long, with its bottom 9 inches above the bottom of the front portion.

The furnaces are two in number, each 4 feet $9\frac{3}{4}$ inches wide by 8 feet long. The crown is an arc of 7 feet 3 inches radius, joined to the vertical sides by quadrantal curves of 8 inches radius. The flat water-space between the furnaces is $6\frac{1}{2}$ inches wide, and between the furnaces and shell 5 inches wide, including thicknesses of metal.

The opening for the furnace door is semi-circular on top, 22 inches wide and 22 inches high. The height from the top of the grate-bars to the top of the furnace is 3 feet. The bridge-wall is 7 inches wide, including thicknesses of metal.

Immediately behind the bridge-wall is a combustion-chamber, separate for each furnace. Its extreme height is 3 feet 2 inches and its length is 3 feet. In cross-section its outline follows the side and top of the furnace, the curve of the lower flue and of the cylindrical part of the shell, from which it is separated by a water-space $3\frac{1}{2}$ inches wide, including thicknesses of metal.

From the combustion-chamber to the back smoke-connection there proceed, for each furnace, three lower horizontal cylindrical flues of 16 inches inner diameter, one lower horizontal flue of 14 inches inner diameter and one of 9 inches inner diameter. All these flues are 9 feet 1 inch in extreme length. The least water-space between them is $4\frac{1}{2}$ inches, including thicknesses of metal.

The back smoke-connection is in common for both furnaces. It is flat on the top, and on the sides and bottom is concentric with the cylindrical part of the shell, from which it is separated by a water-space $3\frac{1}{2}$ inches wide, including thicknesses of metal. The extreme height is 6 feet 4 inches, extreme breadth 9 feet 5 inches, extreme length 3 feet $7\frac{1}{2}$ inches, all in the clear. The flat water-space between the end of the connection and the shell is $4\frac{1}{2}$ inches wide, including thicknesses of metal. Access is had to the connection through a manhole of 18 inches diameter in the back end of the boiler.

From the back smoke-connection to the uptake there are returned over the lower flues and the furnaces 80 horizontal fire-tubes of $4\frac{1}{2}$ inches outside diameter and 4.30 inches inside diameter; length, 16

feet 6 inches. The tubes are distributed in 5 rows vertically and 16 rows horizontally. The least distance from centre to centre of tubes, both vertically and horizontally, is 6.357 inches. The space in the clear, between the bottom of the lower row of tubes and the furnace-crown, is 7 inches. The height from the top of the upper row of tubes to the bottom of the lower row is 2 feet 4 inches. The heating surface of the tubes is calculated for their inside circumference, which is also the case for the flues.

The uptake is in common for all the tubes. The lower portion is rectangular, 8 feet 8 inches in extreme breadth, 55 inches in extreme width to the front of the shell and 31 inches in height. It is fitted with the usual uptake doors, giving access to the tubes for sweeping. The upper portion is irregularly-shaped, drawing in to a circle of 50 inches diameter at the top of the shell.

From the top of the uptake rises the chimney, 50 inches in inner diameter. The lower portion of the chimney, for a height of 12 feet above the top of the shell, is surrounded concentrically by a steam-drum of 90 inches diameter, with a flat top. The portion of the chimney so surrounded, together with the upper portion of the uptake, is steam superheating surface.

All the flat surfaces of the boiler are braced every 7 inches.

The following are the principal dimensions and proportions :

Number of boilers,	2
Extreme length of boiler, exclusive of projecting steam-drum,	25 ft. $\frac{1}{2}$ in.
Extreme height of boilers, exclusive of steam-drum,	10 ft. 9 in.
Extreme breadth of boiler,	11 ft.
Height of steam-drum above the boiler-shell,	12 ft.
Projection of steam-drum forward of the boiler-shell,	1 ft. $3\frac{1}{2}$ in.
Total number of furnaces,	4
Width of furnace,	4 ft. $9\frac{3}{4}$ in.
Length of furnace,	8 ft.
Aggregate area of grate surface,	154 sq. ft.
Number of lower flues,	20
Length of lower flues,	9 ft. 1 in.
Inner diameter of lower flues,	4 of 9 in., 4 of 14 in. and 12 of 16 in.
Number of tubes (iron),	160
Length of tubes,	16 ft. 6 in.

Outside diameter of tubes, ...	4½ in.
Inside diameter of tubes, ...	4.30 in.
Least space between tubes, in the clear, ...	1.857 in.
Aggregate area of heating surface in the furnaces, ...	416.00 sq. ft.
Aggregate area of heating surface in the combustion chambers, ...	262.00 sq. ft.
Aggregate area of heating surface in the lower flues, ...	338.00 sq. ft.
Aggregate area of heating surface in the back smoke-connections, ...	62.70 sq. ft.
Aggregate area of heating surface in the tubes, ...	2971.94 sq. ft.
Aggregate area of heating surface in the uptakes, to 9 inches above tubes, ...	675.36 sq. ft.
Total water-heating surface, ...	4726.00 sq. ft.
Aggregate area of steam superheating surface, ...	418.00 sq. ft.
Distance traversed by the gases of combustion from the centre of the furnace to their delivery into the uptake, ...	40 ft.
Diameter of chimneys (two in number), ...	4 ft. 2 in.
Height of chimneys above level of grates, ...	52 ft.
Aggregate cross-area over bridge-walls, for draught, ...	22.500 sq. ft.
Aggregate cross-area through lower tubes, for draught, ...	22.798 sq. ft.
Aggregate cross-area through the tubes, for draught, ...	16.136 sq. ft.
Aggregate cross-area of the chimneys	27.272 sq. ft.

PROPORTIONS.

Square feet of water-heating surface per square foot of grate surface, ...	30.558
Square feet of steam superheating surface per square foot of grate surface, ...	2.714
Square feet of grate surface per square foot of area over bridge-walls, ...	6.844
Square feet of grate surface per square foot of area through lower flues, ...	6.755
Square feet of grate surface per square foot of area through tubes, ...	9.544
Square feet of grate surface per square foot of area through chimneys, ...	5.647

PADDLE-WHEELS.

The paddle-wheels are of the ordinary radial kind

Diameter from outside to outside of paddles, ...	31 ft.
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Number of paddles in each wheel, ...	26
Length of each paddle, ...	10½ ft.
Breadth of each paddle, ...	1¾ ft.
Deepest immersion of outer edge of paddles, ...	3½ ft.

PERFORMANCE.

The following is the average performance of the *Mary Powell* between the cities of New York and Newburgh, on the Hudson River, during the summer of 1877. The running was very regular, the deviations at any time from the mean being very slight.

VESSEL.	Vessel's mean draught of water, in feet, ...	6½
	Vessel's greatest immersed transverse section, in square feet, ...	198·5
	Vessel's displacement, in tons, ...	881
	Deepest immersion of the outer edge of the paddles, in feet, ...	3·50
	Diameter of the paddle-wheel between centres of pressure of the paddles, in feet, ...	29·50
ENGINE.	Steam pressure in boilers, in pounds per square inch above the atmosphere, ...	28·5
	Proportion of the throttle-valve open, ...	0·75
	Fraction of the stroke of piston completed when the steam was cut off, ...	0·486
	Fraction of the stroke of the piston to be completed when the steam was cushioned, ...	0·232
	Number of times the steam was expanded, ...	1·984
	Vapor pressure in the condenser, in pounds per square inch above zero, ...	2·4
	Number of double strokes made by the piston per minute, ...	21·8
	Temperature of the injection-water in degrees Fahrenheit, ...	68
	Temperature of the feed-water (hot-well) in degrees Fahrenheit, ...	120
	Number of double strokes made per minute by the pistons of the blowing-engines, ...	75
	Number of revolutions made per minute by the fan-blowers, ...	375
	Air pressure in the fan-blower conduit, in inches of water, above the atmosphere, ...	1½
STEAM PRESSURE IN CYLINDER PER INDICATOR.	Steam pressure in cylinder, in pounds per square inch above zero, at beginning of stroke of piston, ...	41·42
	Steam pressure in cylinder, in pounds per square inch above zero, at point of cutting off the steam, ...	31·34
	Steam pressure in cylinder, in pounds per square inch above zero, at end of stroke of piston, ...	16·42
	Mean back pressure against the piston, exclusive of the cushioning, in pounds per square inch above zero, ...	3·55
	Mean back pressure against the piston, inclusive of the cushioning, in pounds per square inch above zero, ...	5·31
	Mean indicated pressure on the piston in pounds per square inch, ...	24·42
	Mean net pressure on the piston in pounds per square inch, ...	22·92
	Mean total pressure on the piston, exclusive of the cushioning, in pounds per square inch, ...	27·15

HORSES-POWER.	{	Indicated horses-power developed by the engines, . . .	1569.432
		Net horses-power developed by the engines, . . .	1473.029
		Total horses-power developed by the engines, exclusive of the cushioning, . . .	1744.884
		Horses-power expended on the cushioning alone, above zero, . . .	165.812
		Horses-power expended on the cushioning alone above the back-pressure of 3.55 pounds per square inch against the piston, . . .	113.112
RATE OF COMBUSTION.	{	Pounds of anthracite consumed per hour, . . .	6059.000
		Pounds of anthracite consumed per hour per square foot of grate surface, . . .	39.286
		Pounds of anthracite consumed per hour per square foot of water-heating surface, . . .	1.280
ECONOMIC RESULTS.	{	Pounds of anthracite consumed per hour per indicated horse-power, . . .	3.855
		Pounds of anthracite consumed per hour per net horse-power, . . .	4.107
		Pounds of anthracite consumed per hour per total horse-power, . . .	3.467
SPEED.	{	Speed of the vessel per hour in statute miles of 5280 feet, . . .	19.200
		Speed of the vessel per hour in geographical miles of 6086 feet, . . .	16.657
		Slip of the centre of pressure of the paddle in per centum of its speed, . . .	16.37
WEIGHT OF STEAM CONSUMED.	{	Fahrenheit units of heat transformed per hour into the total horses-power developed by the expanded steam, calculated for the mechanical equivalent of one Fahrenheit unit, 789½ pounds raised one foot high per minute, . . .	1823195.554
		Pounds of steam of the boiler pressure required to be evaporated from water at the temperature of 120 degrees Fahrenheit, to contain the above number of Fahrenheit units of heat, . . .	1895.741
		Pounds of steam supplied per hour by the boiler to the cylinder, calculated from the pressure at the end of the stroke of the piston and from the back pressure cushioned, . . .	36362.523
		Sum of the two immediately preceding quantities, or weight of steam in pounds consumed per hour, according to the indicator, . . .	38258.264
		Pounds of steam cushioned per hour, . . .	2365.428

German Scientific Credulity.—The well-known German professors, Fechner, Weber and Scherbner, have added their testimony to that of Zollner, in favor of the "spiritualistic" mediumship of Slade. In remarking upon Zollner's curious method of accounting for the phenomena by supposing an unknown fourth dimension of space, Tissandier thinks it strange that men who occupy some of the most important chairs of the German University should be so easily deceived.—*La Nature*.

HARMONIC AND "BASIC" LINES AND TENDENCIES.

By PLINY EARLE CHASE, LL.D.,
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From the third law of motion it follows, as a necessary consequence, that cosmical and molecular bodies act and react in accordance with laws of perfect fluidity and of perfect elasticity. Hence, by introducing formulas of hydrodynamic and of undulatory motion, results can often be speedily reached which would, otherwise, require the use of long and difficult analytical processes.

Challis, in the *Philosophical Magazine*, has discussed a great variety of gravitating, electrical and thermal phenomena, from hydrodynamic considerations. Norton, in the *American Journal of Science*, has applied the principles of pneumatics to similar interpretations. The whole theory of thermodynamics rests mainly upon simple laws of motion, which may be readily deduced, as corollaries, from the fundamental propositions of "Newton's Principia."

In the *Monatsbericht* of the Berlin Academy for September and October, 1878, M. Paalzow describes a method of determining the fundamental lines of the oxygen spectrum with great precision, and publishes the wave-lengths of the five most persistent lines, which he regards as specially characteristic. His measurements are given in millionths of a millimetre, in the following table, together with three other series, which serve, by comparison, to indicate the influence of two co-ordinate laws:

	Paalzow.	Harmonic.	Reciprocal.	Geometrical.
O α	602	602	601.91	599
O β	558.2	558.24	558.27	559
O γ	519	519.24	518.74	520
O δ	481	481.10	480.87	484
O ϵ	453	452.77	452.87	451

In the harmonic series if we divide the first term by each of the successive terms, we get the partial harmonic progression, $\frac{1}{1}$, $\frac{1}{1.0784}$, $\frac{1}{1.1594}$, $\frac{1}{1.2513}$, $\frac{1}{1.3296}$. The harmonic denominators are equivalent to 1, $1 + 29a$, $1 + 59a$, $1 + 93a$, $1 + 122a$, the first difference ($29a$) being also the final difference ($122a - 93a = 29a$).

The reciprocal series is obtained by multiplying 1.6468 successively by 365.5, 339, 315, 292 and 275. The derivation and significance of the common factor, 1.6468, will be explained below.

The terms in the geometrical series are in geometrical progression.

The arithmetical means between the harmonic and reciprocal values are almost identical with Paalzow's measurements. The greatest difference is less than $\frac{1}{2}5$ of one per cent., in O ϵ . The least difference is $\frac{1}{5}15$ of one per cent. in O γ . The other differences range between $\frac{1}{10}0$ and $\frac{1}{3}20$ of one per cent.

In previous communications upon spectral harmonies,* I have shown that the Fraunhofer lines of the solar spectrum represent exponential or geometrical values, while the planetary positions represent linear or arithmetical values, in series which are determined by the relations between density and altitude in elastic atmospheres.

I have also shown, elsewhere:† 1. That the collisions of subsiding particles from opposite diametrical extremities of a condensing spherical nebula, tend to form shells, or rings, of nodal aggregation, at $\frac{2}{3}$ of the radial distance from the centre of the nebula.

2. That centres of linear and spherical oscillation exert an important influence, both upon molar and molecular arrangements.

3. That the nodal resistance of large cosmical bodies tends to form other nodal aggregations, at harmonic intervals, in accordance with the laws of musical rhythm which govern the vibrations of elastic media.

4. That there are reasons for anticipating, in the fundamental oscillations of chemical elements, symmetrical harmonic evidences of the same laws as govern the harmonic nodes of elastic media and the harmonic grouping of planetary systems.

5. That in cosmical or molecular aggregation near the foci of paraboloids, there are three wave systems, with tendencies to nodal collisions and the formation of orbits in which the major axes have successive differences of four times the focal abscissa.

6. That centrifugal velocity varies as the fourth power of tangential velocity in a circular orbit.

The distance of projection against æthereal or other uniform resistance is proportioned to the projectile *vis viva*, or to the square of the projectile velocity. The mean *vis viva* of the spherical undulations

* This Journal, October, 1877, p. 284, etc.

† Proceedings Am. Phil. Soc., volumes xii-xviii.

which are generated by Earth's reaction against Sun's action tends, by the laws which govern the moment of inertia, to form a node at $\cdot 4$ of Sun's distance from Earth, or at $\cdot 6$ of Earth's mean radius-vector.

According to Dr. Fuhg's estimate,* deduced from 6827 measurements of Sun's apparent diameter, Earth's distance from Sun is 214·524 solar radii, and Neptune's distance is 6442·985 solar radii. Having already seen that the Fraunhofer line A, with a wave length of 7612 ten-millionths of a millimetre, is the exponential correlative of the planet Neptune,† we readily find that Earth's mean reaction against Sun's action may be represented by a wave-length of 4215·8. For, $\log. 6442\cdot985 : \log. \cdot 6 \times 214\cdot524 :: 7612 : 4215\cdot8$.

If we regard this reactionary value as a fundamental wave-length for terrestrial chemical elements, we may also (by laws 5 and 6) regard $(\frac{1}{4})^4$ of $4215\cdot8 = 16\cdot468$ as a fundamental increment for such harmonic undulations as may be excited in an elastic medium by inertial resistance.

We have seen in the foregoing comparative table the influence of this fundamental increment upon the oxygen lines. Multiples of the same increment also appear in the differences between the wave-lengths of other elementary spectra and in Lockyer's "basic lines." Take, for example, Gibbs' groupings of corresponding lines,‡ in Kirchhoff's and Huggins' measurements of the spectrum of arsenic :

Kirchhoff.	Huggins.	Normal.
617·54	617·67	617·54
611·69	611·67	611·69
578·95	578·73	578·75
533·55	533·41	533·55

In the normal column, the shortest wave-length, $533\cdot55 = 2^2 \times 3^4 \times 1\cdot6468$; $617\cdot54 - 533\cdot55 = 51 \times 1\cdot6468$; $611\cdot69 - 578\cdot75 = 20 \times 1\cdot6468$; the second set is harmonically connected with the first, for $617\cdot54 \div 611\cdot69 = 1 + \cdot 009575$, and $617\cdot54 \div 578\cdot75 = 1 + 7 \times \cdot 009575$; the only difference between Kirchhoff's and the normal lines is less than $\frac{1}{2}\frac{1}{3}$ of one per cent.; the normal difference is precisely equivalent to Kirchhoff's in the first set, and to Huggins' in the second; the sum of the extreme lines is the same in each column ($617\cdot54 + 533\cdot55 = 617\cdot67 + 533\cdot41$).

* Astron. Nachr., 2040.

† This Journal, *loc. cit.*

‡ American Journal of Science, [2], xlvii, 211.

The group of corresponding lines in the spectrum of zinc* exhibits a similar accordance :

Kirchhoff.	Huggins.	Normal.
636.99	637.37	636.99
610.64	610.89	610.64
589.90	589.90	589.55
472.25	471.98	472.31

In the normal column, $636.99 - 610.64 = 2^1 \times 1.6468$; $610.64 - 472.31 = 84 \times 1.6468$; $636.99 - 472.31 = 10^2 \times 1.6468$; $589.55 = 358 \times 1.6468$. As in the foregoing instance, the sums of the extreme lines are nearly equal in all the columns.

Kirchhoff's copper lines † show a more complicated arrangement :

Kirchhoff.	Normal.
578.67	578.67
529.30	529.27
522.24	522.21
465.64	465.75

In the normal column, $578.67 - 529.27 = 30 \times 1.6468 = a$; $529.27 - 522.21 = \frac{a}{7} = b$; $522.21 - 465.75 = a + b$.

Lockyer has published eight "basic lines," which he regards as especially important, ‡ and which furnish farther illustrations of these various harmonies, some of which I foretold ten years ago. || His lines are given in the following table, together with corresponding theoretical lines, which consist entirely of symmetrical multiples of the fundamental increment :

	Theoretical.	Lockyer's Lines.
$(4^4 + 8^2 + 3^2)$	$\times 16.468 = 5418.0$	5416
$(4^4 + 8^2)$	$\times 16.468 = 5269.8$	5269
		5268
$(4^4 + 7^2 + 3^2 + 2^2)$	$\times 16.468 = 5236.8$	5235
$(4^4 + 7^2 + 3^2)$	$\times 16.468 = 5170.9$	$b^3 b^4$
$(4^4 + 7^2)$	$\times 16.468 = 5022.7$	5017
4^4	$\times 16.468 = 4215.8$	4215

My investigations have been entirely independent of Lockyer's, and

* *Ib.*, p. 212.

† *Ib.*, p. 207.

‡ Proc. Roy. Soc., January, 1879.

|| Proc. Amer. Phil. Soc., x., 103; xii., 392 sqq.; xiii., 245; xvi., 507

I was not aware until I learned by the announcement of M. Dumas, in the *Comptes Rendus*, that the distinguished English spectroscopist had obtained any results which would confirm my anticipations. There has been, therefore, no possible opportunity for shaping my theory so as to accord with the facts. I simply showed, upon mathematical grounds, what *must be* the tendencies resulting from the mutual action and reaction of well-known forces. None of the evidences, which I have here adduced, were either known or suspected to exist when I published my papers. These accordances, therefore, have a double value, for they furnish the physical proof, which is most satisfactory, of *a priori* conclusions, and they show that Lockyer's theories, in addition to the evidence which convinced his own mind, have the corroborating support of principles which are operative wherever a ray of light can go and wherever a physical action can awake an equal and opposite reaction.

In comparing the two sets of wave-lengths in the foregoing table, we see that, while there is the general accordance which gives the most satisfactory indication of natural law, there is sufficient deviation from precise coincidence to show the desirableness of further investigation, in order to secure the greatest possible accuracy of measurements, and to eliminate the effects of disturbing influences. In two instances theory gives only a single line (5269.8 and 5170.9) to represent two lines or a doubled line in Lockyer's system (5269, 5268, b_3 , b_4). I can think of no more probable reason for such doubling than a modification of the other activities by centripetal collisions, in accordance with the first of the foregoing principles. The central line of the five theoretical *incremental* lines (5236.8) represents $\frac{2}{3}$ of the interval between the theoretical representatives of the doubled lines (5170.9 and 5269.8).

Lockyer does not give any estimate of the wave-lengths of b_3 and b_4 . Gibbs gives 5177 as the wave-length of the b line. All the theoretical incremental multipliers are integral squares representing thermodynamic increments of *vis viva*, or of inertial moment, which correspond both to increments of temperature and to distance of projection against uniform resistance. The difference between the initial incremental coefficients in the two sets of symmetrical lines ($8^2 - 7^2$) is 15. The greatest square in 15 is 3^2 , which is the first supplementary increment of the coefficient in each set; the greatest residual square in 15

— 3^2 is 2^2 , which is the second supplementary increment in the first set.

The greatest actual difference between the theoretical and Lockyer's measured values ($5022.7 - 5017 = 5.7$) is only $\frac{1}{400000000}$ of an inch.

This is, however, nearly 35 per cent. of the fundamental increment, a deviation which would materially affect the credibility of the theory if only the simple increment in this single instance were in question. But the deviation is only $\frac{1}{4}$ of one per cent. of the multiple increment, which the law of symmetry requires, ($7^2 \times 16.468$), and less than one-eighth of one per cent. of the total wave-length. If we reduce each of the theoretical values about $\frac{1}{35}$ of one per cent., by dividing by 1.00028, the general closeness of accordance will be more readily seen.

Reduced Theoretical.	Measured.
5416	5416
5268	5269
5268	5268
5235	5235
5021	5017
4215	4215

In my paper upon the "Music of the Spheres,"* I showed that the positions of the various primary planets are more accurately represented by these laws of harmonic oscillation than by either of the merely empirical series that have been devised, and even more accurately than by Peirce's phyllotactic series, which comes next to my own in order of precision, and which may also be explained by harmonic tendencies that were pointed out by Laplace in his "*Mécanique Céleste*." I have since published various confirmations of astronomical predictions,† which it may be well to collect and repeat in this connection, but in order to correct some erroneous impressions in regard to the character of the anticipations and in order to show the remarkable generality of the influences which have justified forecasts in such different fields of investigation, I give below the three known terms on which the prediction was founded, together with eleven subsequent verifications, and one missing term representing a necessary tendency which is mathematically demonstrable and which, I am confident, will be hereafter veri-

* This Journal, September, 1877.

† *Ib.*, Oct., Nov., 1878; March, 1879.

fied. The numerator a represents $\frac{2}{3}$ of Jupiter's semi-axis major, in accordance with the first and fourth of the foregoing principles.

Prediction.		Verification.	
$\frac{a}{1} = 3.469$		Asteroid 87	3.482
$\frac{a}{5} .694$		Venus, mean perihelion	.698
$\frac{a}{9} .385$		Mercurey, mean	.387
$\frac{a}{13} .267$		De la Rue, Stewart and Loewy	.267
$\frac{a}{17} .204$		Kirkwood	.209
$\frac{a}{19} .183$		Watson, II.	.180
$\frac{a}{21} .165$		" I.	.164
$\frac{a}{25} .139$			. . .
$\frac{a}{29} .120$		Von Oppolzer	.123
$\frac{a}{33} .105$		Helios	.106
$\frac{a}{177} .0196$		Themis	.0196
$\frac{a}{321} .0108$		Eunomia	.0108
$\frac{a}{465} .0074$		Phaos	.0075
$\frac{a}{609} .0057$		Iychnis	.0056
$\frac{a}{753} .0047$		Sun's surface	.0047

It has been urged, as an objection to this series, that the existence of any intra-mercurial planets is still a mooted question. The objection may be answered as follows:

1. My investigations have been limited to the demonstration of *tendencies*. After I had found that the influences of harmonic oscillation were traceable from *Alpha Centauri* to the solar system, and also in the position of all the known planets and satellites within our system, it was evident that those influences do not stop at the orbit of Mercury, but that they must extend to the Sun. There was, therefore, little risk in predicting that evidences of such intra-mercurial activity would be found. This prediction was completely verified when De la Rue, Stewart and Loewy announced the discovery of their sun-spot period, with its alternating northern and southern maxima.

2. Tendencies of one kind are often modified or completely over-ridden by tendencies of another kind. In view of the many perturbations to which any intra-mercurial bodies must be subject, it is

reasonable to believe that asteroidal aggregations may be alternately formed and broken up, in the neighborhood of harmonic nodes, and even to look for future conclusive evidence of such shifting arrangements of "cosmical dust." No one who knows the ability and prudent cautiousness of Professor Watson can well doubt that the two unknown bodies which he saw during the last total solar eclipse, were either planetary or cometary.

3. The necessity that rotary oscillation should obey harmonic cyclical laws is just as great as the necessity that the oscillations of planetary revolution should be harmonic. Therefore, the discovery that the three known systems of rotation, in the belt of light planets, in the belt of dense planets, and in the sun itself, are represented by the harmonic series which is established by the combined action and reaction of Sun, Earth and Jupiter, furnished three additional and indubitable verifications of prediction (Helios, Themis, Eunomia).

4. The discovery that the node of Herschel's theoretical "subsidence" (Lychmis), is harmonically intermediate between Sun's surface and "Phaos," and that this ternary system also completes a series of co-ordinate harmonic groupings which begin in the region of the fixed stars and end in the sun, furnished three additional and indubitable verifications of predictions.

5. With regard to the four remaining verifications, we may admit that they are less complete than the others; but the simple names of Kirkwood, Mouchez, Gaillot and Von Oppolzer are sufficient guarantees of the fact that planetoid sun-spots and planetary bodies have been seen in positions all of which can be satisfactorily accounted for by the hypothesis of the four harmonic orbits which these astronomers have computed. Whether the spots and bodies were transient or permanent is a matter of no consequence; the fact remains that the indications exist, and the discovery of those indications furnished four additional verifications of prediction. That there are many others in the fields of astronomy, optics, electricity, thermodynamics, chemistry and general physics, I am sure. That many of them will be discovered hereafter I most confidently and unhesitatingly believe.

REPORT OF THE COMMITTEE ON SCIENCE AND THE
ARTS ON OLSEN'S TESTING MACHINE, RIEHLE
BROS., MANUFACTURERS.

HALL OF THE FRANKLIN INSTITUTE, }
Philadelphia, May 1st, 1879. }

The Sub-committee of the Committee on Science and the Arts, constituted by the Franklin Institute of the State of Pennsylvania, to whom was referred, for examination, Testing Machines and Appliances for Testing, invented by Tinius Olsen and manufactured by Riehle Bros., report that these machines are of various designs, adapted to different materials and purposes, with capacities ranging from 1000 lbs. to 300,000 lbs. In most of them the article to be tested is placed so that one end receives the stress from the source of power, while the other end is acted upon by a system of levers terminating in a graduated beam, so that this stress can be accurately counterbalanced and weighed. But in some of the machines one end of the article is held in a fixed abutment, while the power, which is applied at the other end, has its abutment on the weighing mechanism. In other words, the first-mentioned machines have the article placed between the power and the scales, whilst in the last the power is placed between the article and the scales. The stress is produced in various ways in the different machines, according to their capacities. In the small ones, for testing threads, fabrics, cement, wire, etc., a simple screw is used, the nut being revolved by a hand-wheel or lever. As the machines increase in capacity, so the power to produce the stress is increased, as follows: hand-power through bevel gearing to nut on screw, hand-power through worm and worm-wheel to nut on screw, belt-power through bevel gearing or worm and worm-wheel to nut on screw, hydraulic jack with single pump worked by hand, hydraulic jack with single pump worked by power, and, finally, in the large machines, hydraulic jack with triple pump worked by power.

In all of these machines the weighing apparatus consists of a well-arranged system of simple levers supported on ample knife-edges, the whole being convenient to operate, properly proportioned and handsomely designed, and accurate withal.

The especial characteristics of these machines are the design and

invention of Mr. Tinius Olsen, and most of them are fully described in the accompanying copies of recent patents granted to him.

In the patent of March 25th, 1879, No. 213,525, is described some improvements on their 40,000-lbs. vertical machine. A loose cross-head is suspended by long links from the upper tools, and reaches below the lower tools, for the purpose of enabling compression and transverse tests to be made without any change in the machine, and, at the same time, serving as a guide for the lower tools. This is a decided improvement, adding to the convenience and usefulness, without much increasing the cost.

An arrangement is also shown for lifting the jack after a specimen has broken, or to adjust for length. We do not approve of this, for the reasons that, in our opinion, the chain-wheels would cause one screw to lead the other; that it would be a slow process, running the screws down until the pawls engaged with the rods on the jack; that the pawls would prove troublesome and not act well. This arrangement is also intended to hold down firmly the cross-head of the plunger when a specimen is under stress, so as to prevent this stress from being relieved by any leakage from the jack or connections. For this purpose the device is useful.

The general design of this machine is good. It is compact, while, at the same time, the parts are accessible. The jack is worked by a single hand-pump. The beam and poise are in a convenient position, close to the pump and to the tools. One man can make careful tests, as everything is within easy reach. We can commend this as being a useful and handy size and form of testing machine. It is intended for testing specimens not to a certain size so as not to exceed its capacity.

Patent No. 212,107, granted to Mr. Olsen October 25th, 1878, describes a much larger vertical machine, for testing materials in the actual shapes and sizes used in construction. When practicable, this is a better method, and gives more reliable results. We thoroughly examined a machine of this form of 100,000 lbs. capacity, built for the Pennsylvania Railroad Co.'s shops at Altoona. The arrangement of the platform, levers and jack is remarkably compact, and this, together with the great capability of adjustment of the cross-head carrying the lower tools, enables tests to be made of articles of unusual length. The jack is inverted and bolted to the bed of the machine underneath the platform. This economizes room, but at the expense of convenience for repairs. Instead of a single acting plunger, the jack

has a piston which receives the pressure either on its entire upper surface, for producing the stress, or on its annular under surface, for returning it to position. The pressure is produced by a triple-acting pump worked by belt-power. A rod and hand-lever in front of the platform and immediately below the scale-beam operate the valves, which are so arranged that the flow of the fluid can be shut off without relieving the pressure in the jack or stopping the pump; or the flow can be so directed as to cause the plunger to move in either direction as desired. One man can thus conveniently control the pressure and move the poises without changing position. The location of the specimen is, however, inconveniently high.

A good feature, described in this patent, is that of the adjustable rods, which can be screwed down hard against the cross-head of the plunger, preventing the stress from being relieved by any leakage when the pumps are shut off from the jack for a considerable length of time, as is often desirable; but this does not provide for the relieving of the stress on the specimen occasioned by its own stretching.

Olsen's patent of April 8th, 1879, No. 213,998, describes another form of vertical machine for still heavier purposes. In this case the jack is placed at the top, resting on the weighing mechanism. Its plunger is connected by rods with a cross-head which acts on one end of the piece being tested, the other end of the piece being held by the bed of the machine. The position and arrangement of the cross-heads and tools are very convenient, and long pieces can be readily handled. We regard this as an important feature. The jack, instead of being supported on one main lever, with its fulcrum in the line of strain, in which case it would be in a condition of unstable equilibrium, is made to rest on two levers of different lengths but of the same count, and so placed that the line of strain passes between their fulcrums at distances from each relatively proportional to their lengths. This gives a good broad base to firmly support the jack, and, together with the arrangement of links between the main and intermediate levers, makes an ingenious and efficient construction. Messrs. Riehlé Bros. have never built machines on this plan, but we think it has advantages, and promises to be superior in many respects to the other forms. A drawing of a 150,000-lbs. machine of this style is appended.

Patent of February 25th, 1879, No. 212,734, describes a horizontal machine of 300,000 lbs. capacity, designed especially for testing chain, and built for, and in daily use by, Messrs. Bradlee & Co., of this city.

In this machine the stress is produced by a jack worked by triple-pump driven by belt-power. The jack is at one end of the apparatus and the weighing mechanism and pumps at the other. Heavy timbers are placed between, enabling any length to be obtained, Messrs. Bradlee's machine being about 130 feet over all.

In a horizontal machine of this length and power, special arrangements are necessary to allow for the recoil, both of the jack and of the main weighing levers, which occurs when a heavy chain or other article breaks under strain. This has been well provided for by the devices described in the patent.

Your committee visited Bradlee's chain works, saw the machine in practical use, and tested in it a chain having links made of $3\frac{1}{4}$ -inch round iron, on which was put a strain of 300,000 lbs., the full capacity of the machine. The result was very satisfactory, although, when at its maximum, the machine began to show signs of effort, and could hardly be recommended for continuous work of so great severity.

The triple pump, used to work the jacks of this and other machines, consists of three single-acting plungers, which receive motion, through walking beams, from three cranks at angles of 120 degrees with each other, the objects being to give a steady supply of fluid to the jack and to avoid blows. The stroke of these plungers is made adjustable, so as to vary the power and speed to suit the nature of the test being made. This is accomplished by changing the position of the fulcrums of the walking-beams, as follows: A sliding frame, moved by a screw and hand-wheel, carries a shaft on which are fitted three boxes, each of which has a flat top and bottom fitting between the two halves of the walking-beam, after the manner of the locomotive slide-link. One end of each walking-beam is journaled to a crank, and the other end is connected by links to a plunger. It is evident that when the shaft, which is carried by the sliding frame, is central between the two ends of the beam, the stroke of the plunger will be equal to the entire throw of the crank, or to double its radius. If the frame be moved toward the pump end, this stroke will be diminished, and *vice versa*. As this adjustment can be made without stopping anything, it forms a very convenient and effective arrangement. There is considerable slide of the walking-beams on the fulcrum boxes, owing to the fact that one end of the beams receives a rotary motion from the cranks. This produces an amount of friction that is very noticeable under heavy strains, and which could be suitably provided for by a proper amount of surface.

Olsen's patents of March 25th, 1879, No. 213,525 and No. 213,586, describe tools for holding the ends of specimens while being tested for tensile strength. We did not see either of these in practical operation, but it is claimed that they are a decided improvement on the old methods. We rather question the advisability of making the tool to act as an universal joint, for in case the axis of the test piece were out of line with the axis of stress, this arrangement would be apt to do more harm than good. What is wanted is a device that will infallibly grip each end of the piece so that its centre-line corresponds with the centre-line of pull. The feature of allowing the wedges to accommodate themselves to any irregularities is proper, but the tool should also fill the conditions named above.

The various forms and sizes of testing machines designed by Mr. Olsen and manufactured by Messrs. Richlé Bros. really constitute a new industry in this country, and particularly in this city. Messrs. Richlé Bros. have undoubtedly increased the interest in, and desire for, more extended data as to the qualities of materials. They have placed within the reach of manufacturers good, practical and reliable means of ascertaining these qualities, and it is to be hoped that their efforts will tend to aid the continual improvement of our products, and thus be of great service in the advancement of our mechanical industries.

Although we may criticise some of the details of their machines, and may, in some cases, see room for improvement in workmanship, yet we heartily commend their aims, and think they deserve great credit for what they have already done and are now doing.

Respectfully submitted.

WM. H. THORNE.

L. R. FAUGHT.

J. HAUG.

JOSEPH ZENTMAYER.

WM. D. MARKS.

Improved Vulcanized Rubber.—C. Schwanitz, Jr., of Berlin, uses glycerin in the preparation of vulcanized rubber, in order to secure it from injury by fats and oils. He also passes the finished mass between warmed rolls, in a glycerin bath, in which it is exposed to steam, under a pressure of two or more atmospheres.—*Dingler's Journal*.
C.

MACHINES FOR MEASURING.*

By GEORGE RICHARDS, Philadelphia.

Niceties of measurement, beyond the limit of one-thousandth of an inch for example, are often looked upon by practical men as experiments not required in ordinary practice. This is, however, a mistake, because one-thousandth of an inch is far within a dimension which workmen continually use. One ten-thousandth of an inch, as a term, seems an abstraction, in practice it is a tangible quantity to be felt, seen and demonstrated.

In a paper read before the Institute of Mechanical Engineers in 1857, at Manchester, Mr. Whitworth said: "In the manufacture of my standard gauges of size, the workmen measure to the $\frac{1}{25000}$ of an inch, and these measures are as familiar and appreciable as those of any larger dimensions," so that a machine to record sizes to within the one five-thousandth of an inch, and for comparative tests to one ten-thousandth of an inch, such a one as is shown here this evening, is in every sense a practical working implement.

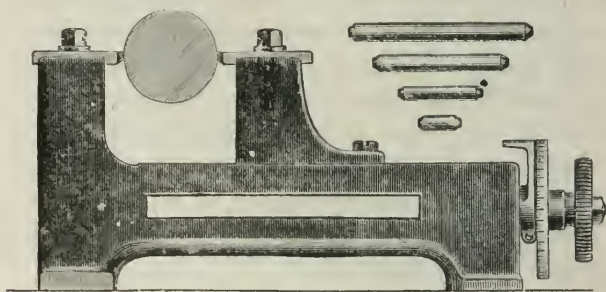
There has arisen a kind of romance in connection with accurate measurements, which is, no doubt, attributable to the secrecy observed in the preparation of gauging tools, perhaps also, in some degree to the nice experiments of Sir Joseph Whitworth showing that one-millionth part of an inch could be indicated, not measured, as was claimed, by one of his machines. The difference between measuring and indicating must always be kept in view when dealing with machines for determining and comparing dimensions.

In making gauging tools, it was at first expected that dimensions could be transmitted from one measuring machine to tools in process by means of carefully adjusted gauges, pins and so on, but it soon became apparent that in order to adjust gauges there must be some means of showing how they approach the finished size, and this applies not only to the last or finishing processes, but also to preliminary ones as well, where allowance has to be made for the distortions and shrinkage of tempering, grinding and so on. By experience the work-

* Extracts from a paper read before the Franklin Institute, April 16th, 1879.

men learn whether one, two or ten "divisions" are enough to allow, and work accordingly. The division meaning one ten-thousandth of an inch by the scale employed on our working machines.

This same system is applicable, as we now think is almost a necessity, in preparing ordinary tools, such as mandrils, reamers, screw taps, and so on. This view has led to the preparation of the machines, one of which is shown here this evening.



Calipering and Measuring Machine.

This little machine, only twelve inches long, has been contrived in such a manner that it will indicate to one ten-thousandth of an inch, or measure absolutely to one-thousandth of an inch or even less if required, and yet it is furnished at a small expense.

It was foreseen that such machines would prove of value in tool-rooms where standard and special tools are continually being prepared. The machine would enable gauges or other exact tools to be made, and at the same time answer the further purpose of keeping gauges of all kinds to standard sizes by detecting wear or derangement. The machine consists of a frame having a sliding stock moved by a screw. On both the frame and sliding head are fixed hardened steel points. The points have been, from experiment, found best when made wide, with double bearing points. This prevents the machines being forced by over pressure.

The screws for moving the points are of course an important part of the machine. These screws are brought within a limit of one in two thousand for accuracy. With each machine is furnished four hardened steel test pins or rods, one inch, two inches, three inches and four inches. These are adjusted, at a temperature of from 70° to 75° , by the standard measuring machine. By employing these pins as starting tests it is evident that in no case will the truth of the screw have to be relied

upon for a range exceeding one-half an inch. I may mention that we are now engaged in experiments to determine some inexpensive mode of correcting the screws of their error, although for all practical purposes this may seem superfluous.

We usually furnish with each machine a table of the screw's errors, so that any one who is curious in the matter can make absolute measurements.

The machine is arranged with an index wheel on which there are marked one hundred divisions, each representing one-thousandth of an inch at the points. Beside, and almost in contact with this index wheel, is a moveable or adjustable pointer. Now, assuming the error, in any case, to be one in two thousand, then, if a half inch is to be measured, the index or pointer is moved forward or back one-fourth of a division, or to make one four-thousandth of an inch at the points.

Screws grow gradually shorter as they are reproduced and their errors are greater than is expected.

As a matter of interest those present who themselves have not investigated, I will now recount some of the principal facts in the derivation of our lineal measures.

In the time of William the Conqueror, it was ordained by statute in England that "the measures and weights shall be true, and stamped in all parts of the country." The standards of weight and measures were deposited in a special building, just as the standards of ancient countries were placed in their temples. The existing imperial yard is so nearly identical in length with those old standard yards of Henry VII. and Queen Elizabeth that it exceeds them by little more than a hundredth part of an inch, a difference frequently found in rules and scales now commonly used. It is also curious to note that the English foot is nearly identical with two-thirds of a natural cubit, known as the *ancient* foot. A double cubit was used in ancient times as a measure of length, and an old Egyptian double royal cubit, found in the ruins at Karnac, may be seen in the British Museum at London. A measure very near equal to two natural cubits was used by the Romans under the name of *ulna* or ell. The *ulna* is mentioned by Pliny, when describing the measurement of the girth of a tree as half the length of the extended arms of a man. It may be fairly assumed that the measure of the double natural cubit, or three feet under the name of *ell* or *yard* came into use in old times as a very convenient measuring unit and found its way into England as the standard unit of length.

The primary standards of weights and measures in England were destroyed by the burning of the houses of Parliament in 1834.

The legal standard unit of measure in England was constructed under the superintendence of the Standards Commission, appointed in 1843, for the restoration of the lost standards.

The act of 1824 under George IV., under the authority of which the lost standards had been legalized, directed that in the event of their loss or destruction new standards should be constructed in accordance with permission contained in the act, by reference to an invariable *natural* standard. After long deliberation the commission made a report stating that to base the standard of measure upon pendulum vibrations was doubtful and erroneous.

They recommended that no change should be made in the unit of measure. A committee of scientific men were appointed to construct a standard by comparisons with the most carefully selected specimens. The magnitude of the operations may be estimated from the fact of the number of micrometer readings for all the comparisons, exceeding two hundred thousand, and amongst the operations it was found necessary to construct an entirely new system of thermometers.

These labors extended over a period of twelve years, and the new standards were legalized in 1855. In order to select the most perfect specimen for the new standard of length, forty line standard yards were constructed, and one of these was finally selected as the imperial standard, not only from its representing, with the greatest precision, the *assumed* length of the last standard yard, but also from the clearness of its defining lines and from its general good workmanship.

A copy of this was then obtained by the standards department at Washington, from which to reproduce duplicates for each State.

Mr. Saxon, then connected with the department, arranged devices for comparing both line and end standards. More ingenuity and care was shown in Washington, perhaps, than ever was before exercised in any country in preparing these comparing devices. Mr. Saxon used a comparing machine, which the members may have seen in the government building at the exhibition in 1876, indicating to millionths of an inch.

In order to magnify the differences of bars, he employed a mirror, arranged to vibrate and be read on the segment of a large circle. In order to avoid tedious labor, he adopted an ingenious plan of marking

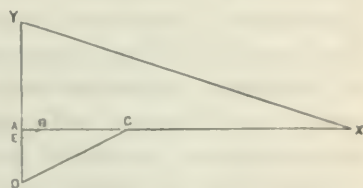
the standards at different temperatures, to allow for differences in length, the range being from 68° to 72° or thereabouts. The expansion of a standard yard, when placed in the instrument and the finger placed near it, is readily seen in the readings.

APPROXIMATE QUADRATURES OF THE CIRCLE.

By PLINY EARLE CHASE, LL.D.

Some of the European technical journals have lately given graphic approximations to the ratio of the circumference to the diameter of a circle. Neither of the solutions, which have fallen under my notice, is so simple or so close as the following:

On the rectangular co-ordinates X, Y , lay off, from a scale of equal parts, $AB = 3$, $AC = 20$, $AX = 60$, $AD = 9$. Join DC and draw BE parallel to DC . Take $EY = AC$, and join XY . Then $XY : AC :: \text{circumference} : \text{diameter}$, *very nearly*.



For if $AC = d$, $AB = \frac{3}{20}d$; $AE = \frac{3}{20} + \frac{9}{20}d = \frac{27}{20}d$; $AY = \frac{373}{400}d$; $XY = \sqrt{9d^2 + (139129 \div 160000)d^2} = 3.14158499d$. The true ratio is 3.14159265, differing by less than $\frac{1}{4100}$ of one per cent. from the graphic approximations, which would give an error of less than $\frac{1}{6}$ of an inch in a mile. The approximate circumference $X'Y'$, for any other diameter, AC' may be found by taking $AX' = 23AC'$, and drawing $X'Y'$ parallel to XY .

The simplicity of this construction is no greater than its practical adequacy. This fact will become evident upon considering that, in graduating a circle of three feet radius, the error for a single degree would be less than $\frac{1}{65000}$ of an inch. In spacing gears with teeth, six inches apart, the error would be less than $\frac{1}{68000}$ of an inch.

Haverford College,

June 16th, 1879.

THE ELECTRIC ARC—ITS RESISTANCE AND ILLUMINATING POWER.

By PROFS. ELIHU THOMSON and EDWIN J. HOUSTON.

From a series of investigations made by us in the winter of 1877-78, and published in the JOURNAL OF THE FRANKLIN INSTITUTE for May and June, 1878, as part of a report of the Committee of the Franklin Institute on Dynamo-Electric Machines, we were led to infer the existence in the electric arc of certain relations between resistance, current strength and illuminating power. Further experiments in the same direction have seemed to confirm these relations. We therefore have taken the opportunity of stating them, believing that they will be of value to other investigators in this field.

The relations existing between arc resistance and current strength, and between current strength and illuminating power, are apparently expressed by the following laws, viz.:

First. *In arcs of equal lengths the resistances are inversely proportional to the current strengths.*

Second. *The illuminating power of an arc is approximately proportional to the current traversing it.*

Third. *In arcs of equal length the total energy given out is proportional to the current strength.*

Whether the above laws will be established for great range of conditions remains for future investigation; and, indeed, when it is considered that it is almost impossible to maintain arcs of equal lengths, the results may be regarded as approximately true, and point to the need of an extended series of experiments, in order that the errors in individual cases may be eliminated. The experiments we are now conducting in this direction are not yet complete, and embrace, besides the laws just stated, other interesting relations. We have thought, however, that the results thus far obtained justify the publication of the above statements of existing relations.

The following theoretical considerations, aside from experimental data, serve partly to explain the first law. An increase of current is attended by a more active transference of carbon vapor from positive

to negative electrode, which would result in an increased breadth of arc and, consequently, decreased resistance.

The bearing of this law on the question of the economical division of the electric current in the production of several arcs in the same circuit, instead of one single arc, is important. It has been held by some that if the intensity of the current be halved, the work being as the square of the current, economic division is impossible. It must not, however, be forgotten, as appears to have frequently been the case, that the above statement assumes that the resistance is constant. With the arc, however, the resistance with a changed current is not constant. If the current be doubled, its resistance is halved; if the current be halved, its resistance is doubled—always assuming the distance between the electrodes to remain constant. The work of the current, therefore, with a given length of arc, is proportional to the current, and not to the square of the current, as has been frequently assumed. The third law expresses this relation, the total energy being the work given out as light and heat, and due to current traversing resistance, which resistance falls as the current increases, and the converse.

The total energy evolved in an arc does not, however, appear to be a measure of the illuminating power of said arc, it having been noticed by us that the total energy in the arc may be the same, while the illuminating power varies considerably. The illuminating power of arcs representing equal amounts of energy evolved, appears to be affected considerably by the distance apart of the carbon electrodes. It is found in practice that, in any case, the maximum illuminating power is obtained when the electrodes are separated to a certain distance. An increase of this distance between the electrodes is attended by an increase in the resistance of the arc and by a decrease in the current strength, not, however, proportional to the increased resistance. Consequently, an increase in the total energy evolved in the arc may take place while an actual decrease of the illuminating power has resulted. This last statement may at first appear to involve a contradiction, but when it is remembered that the greater portion of the light evolved by an arc comes from the intensely heated surfaces of the electrodes, and not from the heated gas stream constituting the arc proper, it can readily be understood that with a large arc, a considerable proportion of the energy will be expended in sustaining the temperature of the gas stream and supplying or making good the heat convected from it to the surrounding air. In an arc of less length, a smaller proportion of the

energy is expended in sustaining the temperature of the gas stream, and the amount of surface of the electrodes heated to intense incandescence is relatively increased.

It is our opinion that the relation between the illuminating power and the current, as expressed by the second law, is necessarily quite approximate, since the distance apart and consequent facility for loss of heat by convection from the electrodes cannot be without influence on the illuminating power.

CENTRAL HIGH SCHOOL,

Philadelphia, June 13, 1879.

ON AN OSCILLATING AND PORTABLE MELTING FURNACE USED IN FRANCE.

By R. GRIMSHAW.

It is strange that attention has not been earlier called to the crude and wasteful manner of mounting and using crucibles for melting and pouring steel and brass. A hundred years has done little or nothing towards changing this part of the constructor's plant. There is everywhere the same mass of brickwork, with cavities lined with refractory brick; a flue at one side leading to a chimney, a grate below, a cover above, and constituting the "natural draft" melting furnace. Suppress the flue and chimney, and add, below the grate, an air blast-pipe, and there is obtained a higher temperature and quicker melting; but in both, the handling of the crucible is the same faulty and dangerous process.

The crucible must be well centered in the fire-place; firmly bedded, lest it tip to one side or the other. The grate-spaces must be kept free from clinker, as the slicing iron is wasteful of fuel and dangerous to the pot. When the metal is melted and ready to pour, skill is required to remove the coke from about the pot, which is then carefully lifted with special tongs, carried to the mould and used to pour from. If there is over seventy-five pounds of metal it takes two men to handle it. The tongs and the air, especially the latter, cool the crucible, so that often the metal is not hot enough for a proper pouring, and when several castings are made from one potful the last is generally run cold. If the pot breaks while being carried, there is loss of metal, risk to the

men, and often moulds spoiled.* Supposing that all goes well in pouring, and the cooled crucible is to be returned to the broken up fire, there is waste of fuel in getting started up again, and of time in arranging. As regards consumption of fuel, foundrymen count fifty pounds of coke, for one hundred pounds of brass, as a minimum; some even say weight for weight. In steel, about three to four times the weight of fuel is often required, and the heats are only say three to four per day of twenty-five pounds each.† For brass, fire-clay pots last a day, say ten to twenty-one runs; graphite gives thirty to forty heats. For steel, graphite pots give on an average six heats before giving out; clay pots stand three heats in twelve hours, averaging 110 to 130 lbs. for the three heats, and are then done.

Now why should the crucible be withdrawn from the bed of coals at each pouring, causing the risk of considerable loss of heat, perhaps burning the workman, and certainly subjecting him to a heat which increases his discomfort, lessens his possible work and causes him to demand extra high wages? Outside of this, breakage of the crucible is a source of loss of metal. Why waste time and fuel in rebedding the pot in the coke for the next melting?

Why not put up crucible and furnace together and keep the metal hot, while saving all the annoyances above mentioned?

The "Oscillating and Portable Melting Furnace," invented by Mr. A. Piat, one of the most important foundrymen and machinists in France, is designed to obviate all these inconveniences, and from personal inspection of its working in his foundry, 85 rue Saint Maur, Paris. I think his claims not altogether unfounded.

The furnace proper is a boiler-iron case, lined with refractory material, and made square so as to save coke; the fuel mostly lodging in the corners and the pot nearly touching the sides. A strong iron band surrounds the case at such a height that it may tip and balance nicely when the pot is about full of metal. By means of these trunnions the furnace is lifted and carried about; levers or carrying bars being employed in case it is carried by men, a crane being employed for the larger sizes. In some of the large furnaces, the device is tipped only

* While a clay pot is tough at steel melting heat, a graphite pot is brittle at any heat and liable to crush with the pinch of the tongs.

† Messrs. H. Disston & Sons use graphite pots No. 50, three heats in thirteen hours, making 425 lbs. of steel for each crucible when worn out, the pots averaging six heats. For melting, they use best Lehigh anthracite coal, 235 lbs. to each 100 lbs. steel melted.

and seldom carried out of place, the metal being run into an ordinary ladle. The refractory lining is of best fire-brick or of well-tamped fettling. The furnace is slightly conical below. On the front side is a pouring hole and spout. At the back there is a large square opening for escape of the gases of combustion. The cover is that ordinarily used in foundries.

So much for the furnace proper. The crucible, which must be fixed therein steadily and permanently, is supported by a "cheese" or flat cylindrical block of refractory material resting on the grate; the spout which connects the front or mouth of the crucible with the pouring orifice of the case, and a wedge also of refractory stuff placed at the back of the pot and holding the whole firm and central. After the first heat or so these pieces become a unit with the pot.

The whole affair rests on two brick supports and receives a blast-pipe below if blast is used. The grate is cleaned every two or three heats by tipping the whole affair and slicing from below.

For brass melting these furnaces are made up to four hundred and even six hundred pounds crucible contents.

For steel and for running pieces over seventy-five pounds weight, the intention is to have a special furnace placed beside other and smaller ones, to receive their contents and carry them to the place of pouring.

For the larger sizes, time is gained and fuel still further saved by adding a recuperator, heating the blast by the escaping hot gases of combustion.

Referring to the annexed engravings, Fig. 1 represents one of the ordinary smaller furnaces mounted upon a special truck or traveling crane, designed to carry it from place to place and tip it, there being a carriage with traverse motion on the truck to enable pouring to be easily accomplished. It will be seen that the pouring is done from an extra pair of trunnions, so placed as to make the stream fall steadily in one place, even while the whole device moves through a large arc.

Fig. 2 shows in section a furnace for thirty to one hundred and fifty kilogrammes of metal, with forced blast and with recuperator.

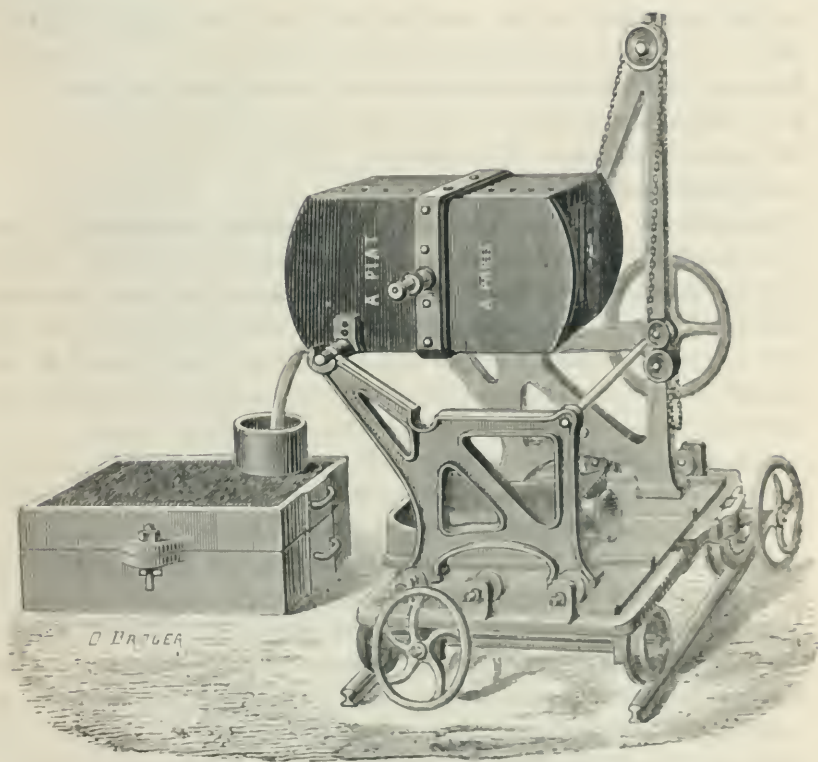


Fig. 1.

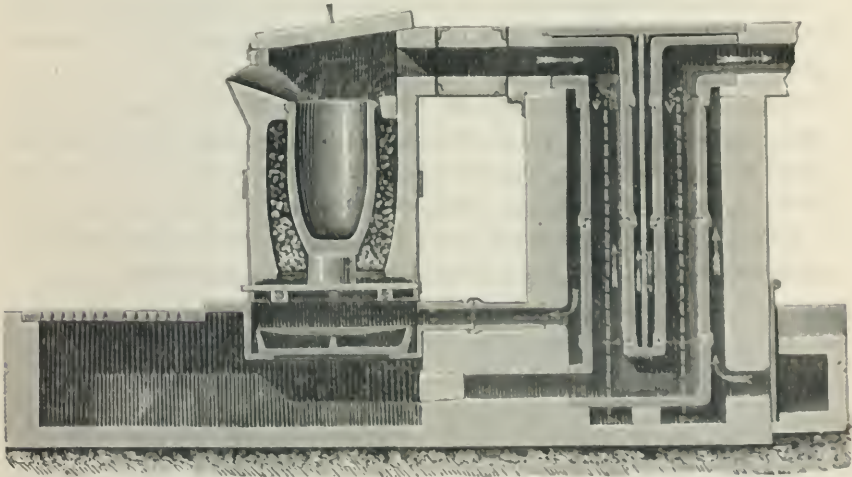


Fig. 2.

THE EFFECTS OF ATMOSPHERIC CHANGES UPON
TEXTILE BANDS.

A paper read before the New England Cotton Manufacturers' Association.

By C. J. H. WOODBURY.

While making some experiments upon the power requisite to operate a spinning-frame under certain different conditions, I found that the power required to drive the frame varied so much with the tension of the bands, that this varying circumstance, for the purposes of experiment, must be eliminated by having an equal tension to the band turning each spindle, that this tension must be known and preserved constant. These requirements seem equally important for economy of production. To turn the spindles with a constant band-tension just sufficient to produce the desired twist without slipping on the whirl, and, on the other hand, avoiding an excessive stress which would cause unnecessary friction, I believe would lead to a saving of power greater than that claimed by any spindle-maker for his spindle over those of his competitors. That is, the difference of power, caused by correct and false band-tension, is greater than that between any two rival spindles. By weighing the band-tension in various mills, it was found that the practice of tying bands lacked uniformity. As an example of this variation, in one mill the bands on a single coarse frame are reported to vary from one to sixteen pounds; in another mill, on finer work, taking a number of spindles at random, the variation was from one-half to two and a half pounds; and in a third mill the band-tension was between the limits of one-fourth to five pounds. Now this haphazard method seems hardly mechanical.

Is it not worth while for each spinner to learn the proper band-tension required for his special work, and then endeavor keep within those limits? The changes constantly occurring in the cotton bands used present an obstacle to carrying out these plans.

In accepting the invitation of your Board of Government, I do not expect to impart any new information upon the question of changes in length of bands, except so far as to give matters of detail connected with accurate measurements of these alterations in a number of bands. These measurements were taken by the following method. Two upright posts were firmly fastened against the wall, about ten feet from each other; the samples of banding were extended between these, one end being fastened to a hook, and the other passing over a leading pulley to a weight. In order that the fibre of which these bands were

composed should be free as possible to expand and contract, it was desirable to use a light weight. By experiment, I found that with a weight of two and a quarter pounds the band deflected only one-tenth of an inch from a straight line. A scale against the wall connected the tops of the upright posts, and a sliding framework carried two plumb-lines (fine wires), hung at right angles, to the banding. When the samples had been under tension of the weight about two hours, this framework was slid, until the wires coincided with the division one hundred inches on the scale; then the corresponding length was marked on the banding with red cotton, and this point, also one hundred inches from the extreme end of the sample, was used to measure the dilation in length, by sliding the framework until the plane of the wires coincided with the mark, then reading the distance on the scale above. In this manner I have taken about forty-five hundred readings, all of which were measured upon the same scale, and under equal conditions of accuracy, during a period of three and half months. The apparatus was simple and rude in general construction, but it was sufficiently accurate to indicate a variation of less than one-fiftieth of one per cent. in the length of the samples of banding.

It must not be understood that by this method I assume to reproduce the exact circumstances to which a spinning-band is subjected when in operation, but simply to maintain the bands subject to a constant tension, under the conditions given above, which being applied in an identical manner to each sample, yield comparative results, giving the correct relations of these samples to each other when acted upon by the same specific causes.

A wet bulb hygrometer hung near the banding, and the readings were noted whenever a measurement of banding was taken. From the comparison of the relative humidity, temperature, pressure of the vapor in the atmosphere, and grains of water per cubic foot of air, it was observed that the changes varied with the differences of the relative humidity, and also increased with the continual tension of the weights.

We "took the weather as it came," until the twenty-third of January, when we endeavored to reproduce the conditions of a dog-day, by admitting steam into the room, until the desired humidity and temperature were obtained. Although the temperature was not in excess of that frequently reached, yet the effect of the moisture made the room seem much warmer, and swarms of insect life threw off their winter torpor, and issued from the cracks in the floors. This moist atmosphere caused all the bands, except the one with the linen core, to

stretch. On the 26th of March the same experiment was repeated with similar results. With slight increase of humidity, the bands contracted very slightly, and with large increase of humidity, the same bands stretched.

Moisture, causing cotton fibres to expand laterally, shortens the length of the fibre by increasing its twist; if by excessive moisture the twist is increased largely, the fibres would be freed from the interlocking of the convolutions to such an extent that, if there was a tension upon the whole cord, it would be lengthened by the slipping of the fibres upon each other. On the other hand, if the band had been stretched to the limit of elasticity, the fibres would be drawn in such close union that they could not separate easily, and only the contracting effects of moisture would be shown, without being followed by excessive stretching. With different textiles, these changes would cause variation to the extent that the adhesion of the fibres to each is changed by alterations in their diameter.

Mr. Edward Atkinson suggested that an absolute band might be obtained by combining different fibres in a proper manner. It was considered essential that the outside of the band should be of cotton, as this seems to be the only substance used for textile bands, which does not polish long before worn out. Two bands of this description were made, with cotton braided outside, one of them with linen and the other with worsted core. This method of combining the two fibres I believe to be original with Mr. Atkinson. Cotton and linen have been twisted together by others, but such combination does not wholly accomplish the object, as the linen seems to lack sufficient resistance to check the stretch of the cotton, when the linen threads are twisted among the cotton. I have been informed that cotton and linen bands have been successfully used for wet-twisting by Mr. T. Merrick, of Holyoke. Mr. Edward Kilburn writes that worsted bands were once used for cotton-spinning at Lonsdale, and resulted in a saving of one-sixth of the power until the expiration of about two months, when they became so polished by wear that it was necessary to take them off.

In three months and a half the linen-core banding stretched one per cent. and cotton banding five per cent. The daily results given are the average of a number of readings.

Your attention is called to the fact, that, while the band with worsted core changes in coincidence with the variations of the relative humidity of the atmosphere, the band with linen core changes in an inverse manner.

Measurements of Textile Bands under constant tension of two and a quarter pounds.

1879.		ATMOSPHERE.				COTTON BRAIDED BANDING						
DATE.		Temperature, Fahrenheit.	Relative Humid- ity.	Vapor Tension In. of Mercury	Water per c. foot, Grains	Linen Core.	Worsted Core.	Cable, no treat- ment	Braided, no treat- ment	Treated with Sulphur	Treated with Fatoline	Made into Push treatment
Months.	Days.											
1	2	3	4	5	6	7	8	9	10	11	12	13
Percentage of Increase in Length.												
January	2	63.0	41	27	2.98	18	72	45	54	54	1.72	.83
	3	60.5	41	16	1.85	35	20	63	78	80	2.12	1.21
	4	61.8	35	19	2.27	38	25	78	86	79	2.15	1.00
	5	67.2	36	26	2.39	30	51	75	87	87	2.08	1.33
	6	69.6	36	26	3.04	35	28	80	90	90	2.25	1.40
	7	65.4	36	21	2.96	30	31	80	90	90	2.75	1.40
	8	55.6	35	24	2.79	12	47	75	81	81	3.00	1.40
	9	70.0	37	28	3.18	34	35	98	1.08	1.00	2.80	1.87
	10	69.0	35	25	3.22	38	37	1.03	1.15	1.08	2.87	1.76
	11	60.0	42	30	3.46	31	40	1.03	1.14	1.07	3.00	1.79
	12	68.3	40	28	3.23	41	42	1.00	1.14	1.05	3.47	1.80
	13	60.3	34	21	2.70	30	37	1.08	1.19	1.11	3.40	1.80
	14	67.0	32	21	2.40	40	34	1.12	1.23	1.17	4.54	1.90
	15	75.0	29	26	2.81	43	38	1.06	1.22	1.16	4.41	1.95
	16	70.7	35	11	1.57	56	46	1.06	1.22	1.13	3.65	1.80
	17	69.0	41	21	3.79	41	48	1.07	1.18	1.12	3.70	1.91
	18	63.5	37	22	2.54	44	37	1.14	1.28	1.17	3.94	2.00
	19	61.6	44	44	2.80	39	48	1.16	1.28	1.21	4.08	2.01
	20	73.2	72	40	6.35	67	1.01	1.43	1.47	1.27	4.70	2.42
	21	65.0	45	30	3.43	40	1.14	3.78	3.54	2.84	4.12	3.80
	22	68.0	47	32	3.68	60	1.03	3.81	3.70	3.14	4.08	4.08
	23	61.0	45	34	2.69	63	1.14	3.08	3.79	3.20	4.27	4.00
	24	70.3	42	21	3.54	58	1.28	3.92	3.80	3.20	4.11	4.04
	25	63.0	42	24	2.76	60	1.28	3.90	3.82	3.20	4.65	4.04
	26	72.0	34	29	3.54	67	1.10	4.05	3.94	3.06	4.42	4.19
	27	66.6	40	26	3.50	69	1.25	4.04	3.94	3.08	4.68	4.11
February	1	70.3	39	29	3.35	68	1.21	4.05	3.91	3.40	4.90	4.21
	2	67.5	39	24	2.84	70	1.21	4.10	4.00	3.40	4.97	4.22
	3	69.0	41	29	3.39	71	1.22	4.10	4.00	3.44	4.92	5.20
	4	70.0	43	32	3.61	71	1.23	4.11	4.00	3.46	4.81	5.22
	5	72.7	41	29	4.79	70	1.30	4.10	4.00	3.45	4.81	5.22
	6	67.0	37	24	2.76	71	1.25	4.10	4.01	3.47	4.92	5.25
	7	73.0	34	27	3.12	72	1.17	4.16	4.04	3.49	4.94	5.30
	8	69.0	38	28	3.23	75	1.18	4.18	4.04	3.52	4.91	5.31
	9	72.0	36	28	3.27	78	1.23	4.14	4.02	3.50	5.11	5.31
	10	71.0	41	31	3.35	70	1.32	4.10	4.12	4.50	5.40	5.40
	11	69.0	45	32	3.08	73	1.30	4.18	4.10	3.61	5.04	5.38
	12	63.0	38	22	2.50	75	1.35	4.23	4.20	3.60	5.00	5.40
	13	69.6	37	27	3.10	81	1.34	4.21	4.21	3.60	5.27	5.41
	14	65.5	33	22	2.40	87	1.30	4.25	4.25	3.74	5.02	5.48
	15	50.0	45	16	1.80	70	1.40	4.24	4.20	3.72	6.10	5.40
	16	71.0	33	25	2.92	80	1.27	4.12	4.20	3.70	5.75	5.40
	17	72.0	38	30	3.43	80	1.37	4.27	4.27	3.78	5.75	5.90
	18	67.6	38	26	1.94	97	1.31	4.33	4.31	3.80	5.87	5.94
March	1	64.3	37	23	2.00	80	1.38	4.29	4.29	3.87	5.90	5.98
	2	65.0	36	28	1.24	85	1.41	4.29	4.41	3.92	5.88	6.06
	3	68.0	30	27	1.08	80	1.44	4.33	4.32	3.97	5.90	6.07
	4	63.0	44	27	3.08	91	1.45	4.41	4.40	4.01	5.86	6.06
	5	61.3	41	28	1.20	79	1.35	4.22	4.29	3.90	5.90	6.00
	6	65.0	40	31	1.78	82	1.32	4.24	4.31	3.81	5.71	6.04
	7	60.0	50	38	4.20	78	1.30	4.21	4.27	3.94	5.40	6.00
	8	68.5	48	44	1.87	75	1.34	4.20	4.29	3.80	5.90	6.00
	9	73.0	70	68	7.48	12	1.31	4.30	4.29	3.83	5.41	6.01
	10	71.5	61	41	4.32	39	1.45	4.30	4.32	4.10	5.41	6.01
	11	60.0	46	31	1.81	76	1.40	4.29	4.30	4.00	5.07	6.04
	12	60.0	40	30	1.60	70	1.44	4.32	4.32	4.01	5.74	6.27
	13	68.5	45	30	1.41	80	1.42	4.28	4.32	4.02	5.75	6.28
April	1	65.0	42	30	1.60	81	1.30	4.30	4.30	4.10	5.84	6.44
	2	68.0	40	28	3.17	92	1.37	4.33	4.37	4.21	5.75	6.48
	3	66.0	33	22	2.00	90	1.35	4.31	4.32	4.20	5.98	6.52
	4	64.7	40	26	3.02	1.00	1.00	4.30	4.30	4.20	5.90	6.51
	5	66.0	45	29	1.54	96	1.46	4.34	4.30	4.22	5.91	6.50
	6	67.0	44	29	3.38	99	1.41	4.30	4.30	4.27	5.88	6.50
	7	66.0	45	29	3.32	1.00	1.44	4.35	4.30	4.27	5.95	6.50

A COMPARISON OF THE PERCENTAGES OF PHOSPHORUS IN BITUMINOUS AND ANTHRACITE COALS.

By C. HENRY RONEY, C.E.

In many metallurgical operations a fuel practically free from phosphorus, as well as sulphur, has been considered a desideratum, and in 1869, being interested in iron ore and coal deposits in both Eastern and Western Pennsylvania, it became necessary for me to determine the percentages of both elements in samples of anthracite coal as shipped to market from some of the collieries of Schuylkill county, particularly as the statement had frequently been made that our Schuylkill anthracites contained injurious amounts of one or both these elements, while the bituminous coals, it was claimed, were comparatively free from both, and were further improved by the coking to which they were subjected before use, as a large part of the sulphur was driven off by that process. I made a series of analyses which satisfied me that most of our leading Schuylkill anthracites, if carefully prepared, picked and screened free from slate, "bony" coal, etc., contained scarcely a trace of phosphorus, but that when carelessly mined and prepared they might contain injurious amounts of that element as well as sulphur. In coking bituminous coal, as little or no phosphorus would be driven off with the volatile bituminous matter, the percentage in the coke would be greater than in the coal from which it is made, the yield of coke by weight being from twenty to forty per cent. that of the coal, depending on the character of the coal and the process of manufacture, although the increase in bulk may be about twenty-five per cent.

In the manufacture of pig iron, with the blast-furnace in good working order, with an acid slag carrying very little iron, very little or no phosphorus is carried off in the slag, as the conditions which favor the perfect reduction of the oxides of iron to the metallic state likewise favor the reduction of the phosphoric acid, which then combines with it, remaining in the pig iron in place of combining with the slag and being removed with it, whether derived originally from the iron ore or fuel; the same process takes place in the Bessemer converter, with a siliceous (acid) lining, and has been one of the chief difficulties with which it has had to contend, as the phosphorus in the

pig iron has not been removed during the process of decarburization but has remained in the steel. The recent announcement of Messrs. Thomas and Gilchrist's process of dephosphorizing iron in the Bessemer converter by the use of a "basic" lining, with which the phosphoric acid can combine and thus be removed from the iron, permitting the use of iron ores containing large percentages of phosphorus which were not heretofore suitable for furnishing iron for the Bessemer process, may also permit the use of fuel which has heretofore been objectionable for the same reason, so that seams of coal which have been useless for this purpose may now be available.

My object has been more to call attention to the subject than to give the results I obtained in detail, and in this connection I submit the following abstract from a very interesting table, giving the percentages of forty specimens of bituminous coal from Western Pennsylvania by A. S. McCreath, Esq., of the Pennsylvania State Geological Survey, presented at the meeting of the American Institute of Mining Engineers this week, showing in one specimen as much as .1667 per cent. of phosphorus in the coal, and .2818 per cent. in the coke made from it:

		pr. ct. in Coal.	pr. ct. in Coke.
Washington county,	maximum	.1667	.2818
" "	minimum	.0011	.0018
Green "	maximum	.0053	.0084
" "	minimum	.0025	.0041
Westmoreland county,	maximum	.0801	.1177
" "	minimum	trace.	trace.
Fayette county,	maximum	.0111	.0164
" "	minimum	trace.	trace.
Somerset "	maximum	.0105	.0135
" "	minimum	.0058	.0074
Beaver "	maximum	.0058	.0094
" "	minimum	trace.	trace.
Cambria "	maximum	.0530	.0638
" "	minimum	trace.	trace.
Blair "	maximum	.0075	.0103
" "	minimum	trace.	trace.
Clearfield county,	maximum)	.0080	.0107
	minimum)		
Huntington "	maximum	.0080	.0093
" "	minimum	trace.	trace.

During the past nine years Dr. C. M. Cresson has been employed by the Philadelphia & Reading Railroad and Philadelphia & Reading Coal & Iron Company in making analyses of coals from their numerous collieries. Many of these examinations have included complete sections of the whole vein, including the slates; others are of large samples of coals, weighing several hundred pounds each, and taken from the schutes from which it is about to be shipped to market. I am also in receipt of a letter from Dr. Cresson, intended to be read at the meeting of the American Institute of Mining Engineers at Pittsburgh, on the same subject, and also in reference to some recent examinations which he has made.

417 WALNUT STREET, PHILADELPHIA, May 14th, 1879.

W. E. C. COXE, Esq.—

DEAR SIR:—By reference, I find that the announcement that the slates accompanying anthracites frequently contained phosphorus, as well as sulphur was made at the meetings of the American Philosophical Society, held May 1st, 1874, and March 5th, 1875. The major part of the phosphorus is in the upper slate, and varying amounts have been got from the dividing and lower slates. I have found that the sulphur is generally distributed and located in a similar manner. A knowledge of these facts enables the selection of anthracite with a minimum both of sulphur and of phosphorus. In fact, the competition for trade has rendered such careful preparation necessary, and there are now mined and sent to market, from Schuylkill county, coals practically free from both phosphorus and sulphur. I have recently made analyses of large samples taken from the cars as they were loaded for market at the Boston Run and Hammond collieries of the Philadelphia and Reading Coal and Iron Company, and find that they do not contain an appreciable amount of phosphorus and of sulphur but 0.1233 per cent. and 0.0822 per cent., respectively. You will perceive, therefore, that the substitution of coke, either in whole or in part, as suggested for properly prepared coals will not improve upon the quality of these coals in respect to the elements named.

Respectfully,

CHARLES M. CRESSON, M.D.

THE REACTION PRINCIPLE OF DYNAMO-ELECTRIC MACHINES.

By PROFS. EDWIN J. HIRSTON and ELIHU THOMSON.

The honor of the discovery of the reaction principle of dynamo-electric machines is very generally accredited, as independent inventions, to Siemens, Wheatstone and Varley, but accorded by priority of publication to Siemens.

The idea of applying currents, generated by a magneto-electric machine, to the strengthening of its own magnets, appears to have been discovered as early as 1855, as will be seen.

It appears from the records of the British Patents that one Søren Hjørth, of Copenhagen, filed an application for letters patent for the invention of "An improved electric battery," as he styled it. The application was sealed the 28th of September, 1855, and dated April 11th, 1855.

The following quotations from the completed specification will suffice to show the nature of the invention.

* * * "Various attempts have been made to produce electricity by means of armatures brought in succession within the action of permanent magnets. Now my invention consists in certain improved arrangements for producing electricity in great quantity and intensity by these means. For this purpose, a series of armatures on a wheel revolving at a slow motion are brought in succession between the poles of permanent magnets and the poles of a series of electro-magnets surrounded with spiral rings or coils of copper." * * *

"The action of the battery is as follows: The permanent magnets acting on the armatures brought in succession between their poles induce a current in the coils of the armatures, which current, after having been caused by the commutator to flow in one direction, passes around the electro-magnets, charging the same and acting on the armatures. By the mutual action between the electro-magnets and the armatures an oscillating force is obtained which, in the result, produces electricity greater in quantity and intensity than has hitherto been obtained by any similar means."

After the above, the step towards the use of electro-magnets only, which retain a slight amount of residual magnetism, as is now common, was but slight; hence the honor of the discovery needs still further division.

Central High School, Philadelphia, June 4, 1879.

REPORT ON THE EXPERIMENTS WITH THE ELECTRIC LIGHT ON THE VICTORIA EMBANKMENT, LONDON.

The joint official report of Sir J. W. Bazalgette, the engineer, and Mr. T. W. Keates, the consulting chemist of the Metropolitan Board of Works, has recently been made public, and is a model of what such a report should be.

For the first time in the history of the electric light, as applied to street illumination, we have a series of data laid before us about whose accuracy there can be no doubt. Hitherto such reports have emanated from either gas-managers or electricians, whose interests—wrongly we think—have been held to be opposed to each other; hence the singular discrepancies in the data which have been issued up to the present time. It must be perfectly understood that we in no way intend to make the slightest imputation against the honor of the authors of these reports; but when one side tells us that the electric light is cheaper than gas, and the other that gas is cheaper than the electric light, we can only account for the discordance of opinion by supposing that the reporters' judgment must have been unconsciously influenced by their anterior convictions. In the present instance we have the conclusions of two eminent public officials, who have no other interests to serve than those of the community at large, and who are wholly independent of the advocates or opponents of either system of lighting.

We regret that we cannot follow the reporters through all the elaborate series of calculations which they have laid before us; we can only gather a few of the results of their carefully conducted experiments. One great point which has been decided on the Victoria Embankment is that the steadiness of the light is in a great measure dependent on the regularity with which the motive power is supplied to the electric machine. In the present case this uniformity of power was secured by the use of a specially constructed 20 horse-power engine, provided with an automatic governor of extraordinary sensi-

tiveness, the whole being supplied gratuitously for three months by Messrs. Ransomes, Sims, and Head, of Ipswich.

The experiments upon which Messrs. Bazalgette and Keates' figures are founded began on January 24th, and were continued until February 5th, Sundays excepted,—or, in other words, for twelve nights,—the engine being driven for 5·5 hours each night, the whole 26 lamps being lighted. The mean daily cost of working the engine, including wages, was found to be £1 9s. 8½d., or 3·24d. per lamp per hour. The cost of the whole plant was £1280, but a smaller engine would be quite sufficient for the purpose; the capital required, therefore, might be reduced to £990.

“The accurate estimation of the amount of light given off by the electric arc and ignited carbons is,” say the reporters, “a matter of great difficulty, so much so that the best results which have been obtained can only be looked upon as fairly approximating to the truth.” This difficulty arises from two causes; first, from the difference in color between the electric light and any standard of light at our command; and secondly, the fluctuating character of the electric light. The photometrical experiments made on the Embankment were—1st, on the naked light; 2dly, on a light with a opaline globe, and 3dly, on a light with a granulated globe. The measurements were made with an ordinary bar photometer, fitted with a movable screen with a star disk.

The standard unit of light which was used was a sperm oil lamp, specially constructed for the purpose by Mr. Sugg, and fitted to the photometer by a peculiar balance, by which the necessity for removing the lamp during the course of any number of experiments is obviated. The unit of light given by this lamp was equal to 16 Parliamentary standard sperm candles. Twenty readings were made on each experiment, both with open and shaded lights,—that is to say, 160 on the naked light, 24 with the opaline globe, and 16 with the granulated globe. The following are the mean results obtained in these experiments:—

Naked light	.	.	.	378·1 sperm candles.
Opaline globe	.	.	.	154·9 “ “
Granulated globe	.	.	.	265·0 “ “

The loss of light produced by the opaline globes is 59 per cent.: by the granulated globes, 29·9 per cent.

Taking the above data as approximately correct, the gross output of light from the twenty Jablochkoff candles amounts to 7562 candles, nearly 60 per cent. of which is absorbed at once by the opal globes. There are also two other sources of loss: first, from the greater thickness of the opal glass in the lower third of the globes; and secondly, from the fact that the most favorable direction for the projection of the light from the Jablochkoff candle is upwards, there being an actual diminution of light horizontally, and still more so downwards.

On the 14th and 15th of March a very important experiment was made, with a view of ascertaining whether the circuits could be increased in length to a considerable degree without diminishing the apparent value of the lights on such circuits. The Westminster and Waterloo circuits—that is to say, the two at each end of the line—were thrown into one, the total length of the wire being 7063 feet, three of the lights being at the Westminster end and the other two at the Waterloo end. The lights burned with apparently equal brilliancy as when short-circuited, and on the following day the length of the line was increased to 8815 feet, or 1.66 mile, but still without any perceptible effect on the light. We believe this is the longest circuit ever attempted to be used with an alternating current machine, and the success of the experiment has a very important bearing on the general question of electric lighting.

We have said before that the cost of a plant necessary for working twenty Jablochkoff lights is £990. The interest on this at 5 per cent. would be £49 10s., and taking wear and tear at 10 per cent., £99, we get a total of £148 10s. Taking the whole time during which the lamps are lighted in the year at 3600 hours, say 10 hours a day, the cost of use of plant for each light per hour is 0.49d. To this we must add 3.24d. per light per hour for the cost of producing the light, and 2d. per hour per candle, making a total of 5.73d. per light per hour all the year round. Let us now compare the cost of gas with the latter figure. The light in the opal globe, as given above, is in round numbers equal to 155 candles, and in the granulated globe to 265 candles. To produce a light equal to 125 candles, one of the larger Sugg burners consumes 48 cubic feet of gas per hour, while to produce a 265-candle light we should require 83 cubic feet per hour. The cost of the former quantity of gas may be taken at 2d., of the latter at 3.5d., or, to put the matter more plainly,

The cost of the electric light is	.	.	5.73 per hour.
Gas equivalent to electric light in opal globe,			2.00 "
" " " " " frosted "			3.50 "

We have therefore, at last, a series of figures on this important subject which cannot possibly be doubted. The experiments which have yielded them have been carried out with the greatest care, and every precaution has been taken to render them so correct that all future cavil or controversy will be avoided; the practical outcome of the matter being that, used in the best possible manner, the amount of illumination in both cases being equal, the electric light costs $1\frac{2}{3}$ times as much as gas.

Sir William Thomson gave some valuable evidence on Friday before the Select Committee engaged in considering the subject of the electric light. He said that whereas one horse-power of energy would only produce 12-candle gas light, it might produce 2400-candle electric light. "The upshot of the experiments made at the factory of Messrs. Siemens, at Woolwich, and at the natural philosophy class of the University of Edinburgh, was that, allowing the practical estimate of one horse-power applied in driving the engine, it had produced 1200 candles of actual visible electric light, half the gross energy going to produce the light while the other half was lost in heating the machine and the wires. As the electric light was such an economical producer he anticipated that it had a great and immediate future before it. He believed before long it would be used in every case where a fixed light was required, whether in large rooms or small ones—even in passages and staircases of private dwellings. There was immense promise in the actual work carried out by practical men in the present day. There was a prodigiously greater economy in the transmission of mechanical force into energy in the case of the electric light than in the case of gas. With regard to regulators for the electric light, he had seen one the previous day—the Siemens regulator—which gave a steady, pure and quiet light. The electric light was especially adapted for being placed high where it illuminated a wide area. It might be put upon an iron pole raised 60 feet high, or the old French plan of swinging a lamp on a wire from one side of the street to the other might be followed with advantage. Such a plan would be useful in doing away with the necessity for opal globes, which destroyed a large quantity of the illuminating quality of the light. Indeed, he was surprised that these globes had ever been used, wasting as they did 50 or 60 per cent. of

the illuminating power. He considered that the advantages of using the electric light within buildings would be very great, because of the small effect it would have when compared with gas in heating and vitiating the atmosphere. In the case of electricity, the waves of light only became converted into sensible heat, not in the air, but on the ceiling or walls and floor of the room after they had done their work. With regard to the subdivision of the light, according to practical experiments, if the same amount of energy that was used in producing one large light was employed in producing ten feebler lights, none of those lights gave one-tenth of the amount of illumination of the one large concentrated light. Still there was nothing mathematically impossible in the matter, and it was quite possible that a plan of subdivision might be found by which the ten feebler lights would give a sum of illumination equal to that of the one larger light. He considered that the electric light as now developed was fit for use in large rooms."

A Fatal Colliery.—In a recent explosion of fire-damp, in the Agrappe mine, near Mons, 147 lives were destroyed. Thirty years ago, in an explosion which was caused by the imprudence and obstinacy of some of the workmen, 750 men were lost. Four years ago, 118 miners were killed in the same shaft, and work was resumed in it only two months before this third fatal explosion.—*La Nature*. C.

The Longest Tunnel in the World.—Notwithstanding the magnitude of the St. Gothard Tunnel, its length is not so great as that of the gallery of the Joseph II. mine, in the Hungarian valley of the Grau. It was begun in 1782, to drain the mines of Schemnitz, and has been continued, with many interruptions, until its recent completion. The Sutro Tunnel is 6147 metres (3·82 miles) long; the Mont Ceniz, 12,233 metres (7·6 miles); the St. Gothard, 14,920 metres (9·27 miles); the Joseph II., 16,538 metres (10·28 miles). The total cost of the last tunnel has been 11,497,500 francs (\$2,299,500). It is of great geological value; it has opened a new region of rich mining property; it has supplanted all the pumping engines, thereby effecting an annual saving of \$50,000; it has opened the way for the employment of new inventions and new methods of working which will render all the tributary mines more productive and more profitable.—*La Nature*. C.

Artificial Lithographic Stone.—A. Regel, of Gotha, has found that artificial plates of Portland cement may be used with advantage in lithography as a substitute for the costly Solrhofen stone.—*Diugler's Journal*. C.

Hydraulic Tubing.—G. Parravicini recommends a more general substitution of terra cotta and cement tubes for those of brick and stone, in sewers, water-ways and other similar underground structures. Among the advantages which he enumerates are: 1, Reduced cost of foundations; 2, Ease of building in running water; 3, Saving of time in construction; 4, Possibility of carrying on the work in winter and at other times when labor is cheap.—*Il Politecnico*. C.

Steamship Improvement.—It is interesting to compare the present performance of the transatlantic steamers, and their relative consumption of coal, with the same data in 1840. The *Britannic*, of the White Star Line, made average passages in the year 1877 in 7 days 10 hours and 53 minutes, consuming less than 250 kilogrammes (551·155 lbs.) of coal for 1000 kilogrammes of freight, and having an average speed of 15·6 knots per hour. On the other hand, in 1840 the *Britannia*, the most famous steamer of its day, used 2400 kilogrammes (5291·091 lbs.) of coal per 1000 kilogrammes of freight, with an average velocity of only 8½ knots per hour.—*Fortschr. der Zeit*. C.

Unity of Geological Forces.—W. H. Herneite explains the great differences in the figures of the planets, by the combined action of centrifugal force and the distribution of solar heat. Mars, for example, is flattened at the poles by a percentage which is nine times as great as that of the Earth, although the ratio of the centrifugal force to gravitation is nearly the same in each of the two planets. In the Earth, the free circulation of the ocean waters makes the figure of the globe nearly the same as if it was entirely liquid. But in Mars the oceans are mostly of a Mediterranean character, so that the equatorial expansion by heat and the polar expansion by cold produce an increased relative polar compression. Herneite gives reasons for thinking that the play of volcanic forces has been of much less importance than has been commonly imagined. He examines especially the theory that volcanos act as safety-valves, and finds that, for such a purpose, each volcanic chimney should have an area of more than a square kilometre, (1093623·11 square yards).—*Les Mondes*. C.

Comparative Strength of Wood and Iron.—Heim finds that, in most cases, a uniform strength of structure can be more economically secured by the use of wood than by the use of iron. The strength of wood is proportioned to its density, and can be increased by its immersion for two or three days, or until complete saturation, in linseed oil, kept at a temperature of from 150° to 212° Fahr.—*Fortschr. der Zeit.* C.

Artificial Imitation of Native Iron.—S. Meunier has confirmed his theory in regard to the terrestrial origin of the supposed meteoric native iron of Greenland, by the action of protochloride of iron and chloride of nickel upon fragments of iron in a porcelain tube. He thus obtained a fac-simile, upon a microscopic scale, of the huge blocks which were brought from Disco by M. Nordenskjöld.—*Comptes Rendus.* C.

Relations of Fusion to Molecular Oscillation.—R. Pictet supposes that the temperature may be represented by the length of the calorific oscillation of the molecules of a body, and from this hypothesis he deduces the two following laws: 1. The higher the melting point of a solid, the shorter are the molecular oscillations. 2. The products of the temperatures of fusion by the lengths of oscillation, are constant for all solids. The laws are confirmed by all the metals of which the coefficients of dilation have been determined with sufficient accuracy. Similar relations hold good for the elements of volatile liquids, when they are compared at their boiling points. These laws may be classed with the law of constancy between the products of atomic weights and specific heats.—*Comptes Rendus.* C.

Microphonic Study.—Boulet de Paris has experimented with a microphonic transmitter, in which the carbons, instead of being pressed by a spring, are simply kept in contact by a bit of paper folded like a V. It was so sensitive that, with a single Leclanché cell, and at a distance of 500 metres (1640·4 feet), the receiving telephone reproduced the message so that it could be heard in all parts of the hall. By increasing the amplitude of the vibrations he found that they were of two kinds: 1. Large vibrations, or rather undulations, which always occurred in the same order for any given word or vowel. 2. Small vibrations, very short, very numerous, looped upon the larger ones. He thinks that the undulations are due either to the force of the breath which necessarily accompanies the emission of the voice, or to the inertia of the instrument.—*Comptes Rendus.* C.

Artificial Ultramarine.—This product has almost wholly supplanted the cobalt dyes, and it has largely taken the place of Prussian and other blues. In 1862 the total production was 3556 tons; in 1872 it had risen to 8585 tons, exclusive of the amounts manufactured in an English and in an American factory. The present product is probably over 12,000 tons. The materials employed in the manufacture are sulphide of sodium, sulphate and carbonate of soda, sulphur, carbon and silicates of alumina.—*La Gaceta Indust.* C.

Franklin Institute.

HALL OF THE INSTITUTE, June 18th, 1879.

The stated meeting was called to order at 8 o'clock P. M., the President, Mr. William P. Tatham, in the chair.

There were present 137 members and 93 visitors.

The minutes of the last meeting were read and approved.

The Actuary presented the minutes of the Board of Managers, and announced that, at the last meeting, 11 persons were elected members of the Institute, and reported also the following donations to the Library:

Eighth Annual Report of the Board of Regents of the Smithsonian Institution. From the Institution.

First to Fourth Catalogues of the Central University, Richmond, Ky. From Prof. Tobin.

Programme of the Seventh Annual Exhibition in Chicago. From the Exposition Company.

Industrial Art Education. By W. Smith. From the Author.

Third Report of the New York State Survey. From James T. Gardner, Director.

Ninth Report of the Board of Trustees of the Illinois Industrial University. From the Board.

Seventh Report of the Board of Directors of the Zoological Society of Philadelphia. From the Society.

Great Blast at Glenton. By Ellis Clark, Jr. From the Author.

Report of Permanent Committee of the First International Congress at Vienna.
From the Meteorological Committee of the Royal Society, London.

Mercantile Library. Finding List.

From the Library.

Lists of Beacons, Buoys, etc., in the Light House Districts.

Annual Reports of the Light House Board.

Experiments on Babbage's Method of Distinguishing Light Houses.

Compilation of Public Documents and Extracts from Reports and Papers Relating to Light Houses.

List of Lights on the Northern Lake and River Coasts of the United States.

Specifications, etc., for Light Houses at Thirty-mile Point, N. Y., Hilton Head Range, Fort Ripley Shoal, etc.

Light House Papers.

Laws Relating to the Acquisition of Title to Land Required for Light House Purposes.

Laws of the United States relating to the Establishment, Support, etc., of Light Houses, Vessels, etc.

Extracts from Report of Her Britannic Majesty's Commission Appointed to Inquire into the Condition, etc., of Lights, Buoys and Beacons.

List of Light Houses, Lighted Beacons, etc., on the Atlantic, Gulf and Pacific Coasts of the United States.

Charts showing Positions, Range, etc., of Lights in Light Houses on the Coast.

Plans, Drawings, etc., of Light Houses, Buoys, Fog-whistles, etc.

From the Light House Board.

Ninth Report of the President and Directors of the Lake Shore and Michigan Southern Railway Company. From the Company.

Revised Regulations for the Government of the Life-saving Service. Reports of the Operations of the Life-saving Service.

From the Life-saving Bureau, Washington.

Report of the Superintendent of the Seventh Census.

From the Census Bureau.

Useful Information Pertaining to the Generation and Use of Steam. By Babcock & Wilcox, New York.

From the Authors.

Pottery and Porcelain at the Paris Exposition.

From J. E. Caldwell & Co., Philadelphia.

Quarterly Report of the Chief of the Bureau of Statistics.

From the Chief of Bureau, Washington.

Notes on the Life and Character of Joseph Henry. By James C. Welling. Philadelphia.

From the Author.

Graphical Method for Finding the Real Roots of Numerical Equations of any Degree. By W. H. Hunt.

From W. H. Bixby, New York.

Annual Report of the Secretary of the American Iron and Steel Association.

Proceedings of the Convention of Iron and Steel Manufacturers and Iron Ore Producers, held at Pittsburg.

From the American Iron and Steel Association.

Report on the Bridging of the Mississippi River. By G. K. Warren.

From the Chief of Engineers.

Documents Relative to the Origin and History of the Smithsonian Institution. By W. J. Rhees.

From the Institution.

Specifications and Drawings of Patents issued from the United States Patent Office, for January and February, 1879.

From the Patent Office.

Annual Report of the Chief Signal Officer to the Secretary of War.

From A. J. Meyer, Chief Signal Officer.

Alphabetical Index of Patents and Applicants for Patents of Invention.

From the Commissioners of Patents, London.

Report on Safety-valve Tests made at the United States Navy Yard, Washington.

Iron Manufactures in Great Britain. By R. H. Thurston.

Annual Report of Chief of Bureau of Steam Engineering.

Report of the Board to Recommend a Standard Gauge for Bolts, Nuts, etc., for U. S. Navy.

Report on the Herreshoff Boiler, submitted to the Navy Department.

Report on the Ashcroft Furnace-doors and Grate-bars.

Report on the Murphy Grate-bar.

Report on the Two Kinds of Coal Submitted by the Chesapeake & Ohio Railroad Coal Agency.

Register of the Commissioned, etc., Officers of the Navy of the United States, including Officers of the Marine Corps.

From Chief Engineer Fitch.

Resources of the United States for Sheep Husbandry and the Wool Manufacture. By J. L. Hayes.

Sheep Husbandry in the South. By J. L. Hayes.

American Textile Machinery. do.

Protective Question Abroad. do.

Protective Question at Home. do.

Notes upon Indigo. do.

Tariff Policy of England and of the United States Contrasted. By E. B. Bigelow.

Awards and Claims of Exhibitors at the International Exhibition.

Bulletin of the National Association of Wool Manufacturers. Vol. 5 to Vol. 9.

Directory of the United States Textile Manufacturers.

From the National Association of Wool Manufacturers.

Report of the Commission on Site for Naval Observatory. Washington.

Investigation of Corrections to Hansen's Tables of the Moon. By S. Newcomb. Washington.

Report on the Difference of Longitude between Washington and Detroit, Mich., etc. By J. R. Eastman. Washington.

Report on the Difference of Longitude between Washington and St. Louis. By Wm. Harkness. Washington.

Report on the Difference of Longitude between Washington and Ogden, Utah. By J. K. Eastman. Washington.

Meteorological Observations made at the United States Naval Observatory. Washington.

Tables of Instrumental Constants and Corrections for the Reduction of Transit Observations made at the U. S. Naval Observatory. Washington.

Zones of Stars Observed at the United States Naval Observatory with the Meridian Circle.

Uranian and Neptunian Systems Investigated with the 26-inch Equatorial of the United States Naval Observatory. By Simon Newcomb. Washington.

Zones of Stars Observed at the United States Naval Observatory with the Meridian Transit Instrument. Washington.

Zones of Stars Observed at the United States Naval Observatory with the Mural Circle. Washington.

From Prof. E. S. Holden, Librarian U. S. Naval Observatory.

Papers relating to the Foreign Relations of the United States. Washington.

Annual Reports upon the Commercial Relations of the United States with Foreign Countries. From the Secretary of State.

The Secretary read a memorial of Dr. Hays, prepared by Mr. Frederick Fraley, chairman of the committee appointed on the subject,

which, on motion of Mr. Orr, was ordered to be published in the JOURNAL.

MEMORIAL OF DR. ISAAC HAYS.

By the death of Dr. ISAAC HAYS the Franklin Institute has lost one of its original members, who for many years of its early history and labors occupied a prominent official position. Born in the city of Philadelphia of most respectable lineage, educated in her best schools and in the University of Pennsylvania, he was prepared by these advantages to occupy prominent positions and to participate in great public concerns. His career was one of great usefulness, and his services to the Institute were of great value. He knew its founders and original members well—they were endeared to him by ties formed in youth, which were strengthened by years and by congenial tastes and labors. In the profession of medicine he soon attained high rank, and his reputation for skill was of universal acceptance. As a member and officer of the American Philosophical Society, of the Academy of Natural Sciences, and other institutions, he was constantly engaged in scientific labors and in the pursuit of useful knowledge. As the life-long editor of the oldest and best medical serial in the United States, he was the means of diffusing most widely all the results of medical experience and practice, and he thus became medically known throughout the world as an able and distinguished man. For many years he devoted himself to the relief of the blind, and of those suffering from diseases of the eye in Wills Hospital, and these services, rendered without compensation, are among the evidences of his enlarged philanthropy. He thus fulfilled all the duties of a man and a citizen with great ability and faithfulness, and finally sank to his rest, after reaching upwards of four score years, crowned with the respect and honors of his fellow-citizens. While we mourn his loss we are thankful that he was spared to us so long for an example, and we pay this tribute to his memory in the hope that in the future many may be induced to emulate his worth, and in their day and generation to be as useful and worthy as he was.

Mr. Henry Bentley read the paper announced for the evening, on "Electro-chemical or Loud-speaking Telephones," and the large audience present had the opportunity of hearing the instrument for the first time in this country, and noticing the wonderful clearness of the speech uttered and the various airs, played at a distance.

After a discussion of the subject by Mr. Nystrom, Dr. Rogers and Mr. Orr, Mr. Roberts moved that a vote of thanks be tendered to Mr. Edison and to Mr. Bentley for the great pleasure given by them, and that the Secretary transmit a copy, which was unanimously carried.

Mr. George Burnham, Jr., made some remarks on a new Casting

Cleaning Brush as applied to the Stow Flexible Shaft, and the instrument was shown in operation. Mr. Richards and Mr. Eldridge spoke on the subject.

Mr. Richards explained an improvement on his Measuring Machines, devised by Mr. George Richards, and which adds little to the cost.

The Secretary exhibited one of Grossmann's Micrometers, the outside circle graduated in hundredths of a millimetre and the inside in thousandths of an inch, as well as a large model of a lever escapement; inserted teeth for circular saws; a new insulating material of cork and paper pulp; a new Algerian paper stock; an oiler for a loose pulley as used in France; a specimen of a square hole drilled in a piece of brass with a triangular rotating drill and French printed matches made with an automatic machine from a round block of wood.

A letter from Mr. Van Allen was read, describing the method of drilling holes only the one-hundredth of an inch in pieces of osmiridium, as devised by Mr. John Holland, of Cincinnati, for the Mackinnon Fountain Pen.

Sharpened copper shafts of the required diameter are made to revolve at the rate of about five thousand revolutions a minute. The particles of osmiridium are soldered to a brass plate and the holes started with a diamond drill. These holes are then gradually deepened till cut through, by touching them to the revolving copper shafts.

Turkish emery and oil are the only assistants. As the shafts are quickly dulled, they are as speedily sharpened, while in motion, by a touch of the file.

The Secretary read an account of Harrington's Screw Hoisting Machines, and a large model was also shown, also the Blacklock Fan Attachment for Sewing Machines.

Mr. Moore exhibited and described his Sanitary Closet, and the subject was discussed by Mr. Ware and Dr. Rogers.

Mr. Lance described his new method of propelling boats by air, a small model being shown. Mr. Jones spoke on the subject.

Mr. Jones announced the death of Mr. William Adamson, and offered the following resolution, which was adopted:

Resolved, That a committee be appointed by the President to prepare a memorial of our late fellow-member.

On motion, the meeting adjourned until the third Wednesday in September.

ISAAC NORRIS, M. D., *Secretary pro tem.*

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THE COMPUTATION OF THE MOMENT OF INERTIA OF A GIRDER BY RECTANGULAR COMPONENTS.

By ROBERT BRIGGS and LUIGI D'AURIA.

The usual method of computing the moment of inertia of a girder around its neutral axis is first to lay off the section into rectangular surfaces whose several centres of gravity are supposed to be crossed by lines parallel to the axis of the system which passes through the common centre of gravity. An axis is assumed, and the distances from this axis to centers of the rectangular components is then taken; when the sum of those distances on the one side of the axis, multiplied into the surfaces, will be compared with the sum of the distances on the other side of the axis multiplied into the corresponding surfaces, and by trial of new axes, finally these two sums will be made equal, when the axis thus determined will be the true neutral axis of the system. Then, to obtain the moment of inertia of the system, the well-known rule of procedure is to take the sum of the moments of the several rectangular components referred to their own neutral axes by the formula. $I = \frac{1}{12} bh^3$ (where I = moment of inertia, b = breadth and h = height of the section), to which sum is added the sum of the squares of the distances, of the several component axes

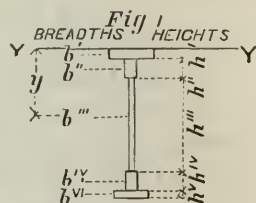
from the general axis of the system, multiplied by the surfaces respectively.

For a girder composed of a small number of components, there is to be found in most text books some formula which will give an accurate result, with possibly a few less figures than is required for the detailed estimate above described; but the application of these formulæ becomes a blind following to any who are not fresh in the exact method by which these formulæ were derived, and generally the application of such formulæ cannot be extended to beyond three, or at most five, components.

The writer of this note was engaged in laborious computing the common centre of gravity and moment of inertia of a girder after the methods described, when he asked the assistance of Prof. D'Auria to test his calculations. The methods followed by the latter were found to present some novelty in symmetric arrangement and convenience in application in general for any number of components, such as to warrant publication.

The position of centre gravity in a surface composed of a system of rectangular components is given as follows:

The line $\overline{YY}$ is taken as the origin,
 $\therefore b =$ respective breadths,
 $h =$ respective lengths of sides of each section,
 $y =$ distance of line of centre of gravity
 from $\overline{YY}$.

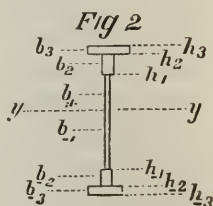


$$\therefore y = \frac{\text{sum of moments of surfaces from } \overline{YY}}{\text{area of surfaces}} =$$

$$\frac{b_1 h^i (\frac{1}{2} h^i + 0) + b_2 h^{ii} (\frac{1}{2} h^{ii} + h^i) + b_3 h^{iii} (\frac{1}{2} h^{iii} + h^{ii} + h^i)}{b_1 h^i + b_2 h^{ii} + b_3 h^{iii}} \dots (I)$$

The moment of inertia referred to the line of centre of gravity (y , as above found) can thus be ascertained as follows:

The line $\overline{yy}$ is taken as the neutral axis,
 $\therefore b =$ respective breadths,
 $h =$ respective distances from the neutral axis,
 $I =$ moment of inertia,
 $Z =$ general value for h .



$$\therefore I = b_1 \int_0^{h_1} z^2 dz + b_2 \int_{h_1}^{h_2} z^2 dz + b_3 \int_{h_2}^{h_3} z^2 dz + \dots + b_n \int_{h_{n-1}}^{h_n} z^2 dz$$

$$+ b_{-1} \int_0^{h_{-1}} z^2 dz + b_{-2} \int_{h_{-1}}^{h_{-2}} z^2 dz + b_{-3} \int_{h_{-2}}^{h_{-3}} z^2 dz + \dots + b_{-(n-1)} \int_{h_{-(n-1)}}^{h_{-n}} z^2 dz \quad (\text{II})$$

and integrating between limits

$$I = \frac{1}{3} [b_1 h_1^3 + b_2 h_2^3 - b_2 h_1^3 + b_3 h_3^3 - b_3 h_2^3 + \dots + b_n h_n^3 - b_n h_{n-1}^3$$

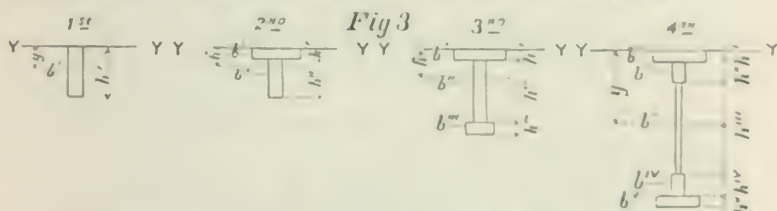
$$+ b_{-1} h_{-1}^3 + b_{-2} h_{-2}^3 - b_{-2} h_{-1}^3 + b_{-3} h_{-3}^3 - \dots + b_{-(n-1)} h_{-(n-1)}^3 - b_{-n} h_{-(n-1)}^3] \quad (\text{III})$$

$$I = \frac{1}{3} [h_1^3 (b_1 - b_2) + h_2^3 (b_2 - b_3) + h_3^3 (b_3 - b_4) + \dots + h_{n-1}^3 (b_{n-1} - b_n) + h_n^3 b_n$$

$$+ h_{-1}^3 (b_{-1} - b_{-2}) + h_{-2}^3 (b_{-2} - b_{-3}) + h_{-3}^3 (b_{-3} - b_{-4}) + \dots +$$

$$h_{-(n-1)}^3 (b_{-(n-1)} - b_{-n}) + h_{-n}^3 b_{-n}] \quad (\text{IV})$$

The symmetrical form of these equations allow any number of values to be taken. For convenience of reference, the following examples are exhibited: Formule for position of neutral axis = y .



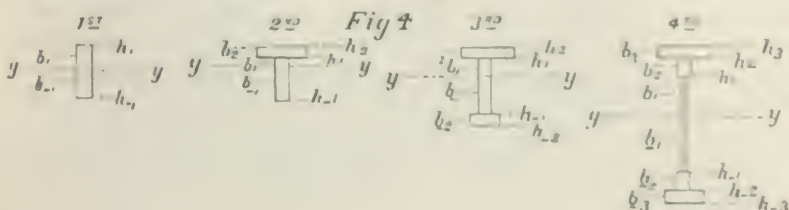
$$\text{1st. } y = \frac{b_1 h^1 (\frac{1}{2} h^1)}{b_1 h^1} = \frac{1}{2} h^1 \quad \text{2d. } y = \frac{b_1 h^1 (\frac{1}{2} h^1) + b_2 h'' (\frac{1}{2} h^1 + h'')}{b_1 h^1 + b_2 h''} \quad (\text{V})$$

$$\text{3d. } y = \frac{b_1 h^1 (\frac{1}{2} h^1) + b_2 h'' (\frac{1}{2} h'' + h^1) + b_3 h''' (\frac{1}{2} h''' + h'' + h^1)}{b_1 h^1 + b_2 h'' + b_3 h'''} \quad (\text{VI})$$

$$b_1 h^1 (\frac{1}{2} h^1) + b_2 h'' (\frac{1}{2} h'' + h^1) + b_3 h''' (\frac{1}{2} h''' + h'' + h^1) + b_4 h^{iv} (\frac{1}{2} h^{iv} + h''' + h'' + h^1) + b_5 h^v (\frac{1}{2} h^v + h^{iv} + h''' + h'' + h^1)$$

$$\text{4th. } y = \frac{\dots}{b_1 h^1 + b_2 h'' + b_3 h''' + b_4 h^{iv} + b_5 h^v} \quad (\text{VII})$$

Formula for moment of inertia = I



1st. Where $b_1 = \underline{b}_1$ and $h_1 = \underline{h}_1$; $I = \frac{1}{3} [h_1^3 \underline{b}_1 + \underline{h}_1^3 \underline{b}_1] = \frac{2}{3} (h_1^3 \underline{b}_1)$ (VIII)

(If we take $h_1 = \frac{h}{2}$ when $h =$ total height of beam then from

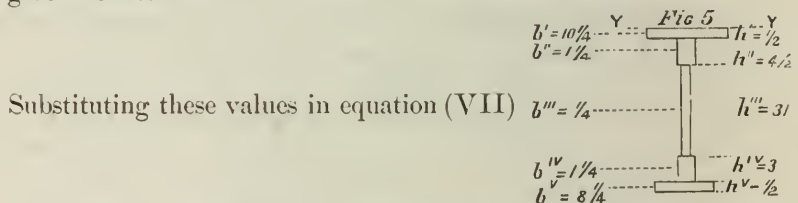
VIII, $I = \frac{2}{3} \left(\frac{h}{2} \right)^3 \underline{b}_1 = \frac{1}{12} h^3 \underline{b}_1$, which is the usual formula given for the moment of inertia of this section.)

$$2d. \quad I = \frac{1}{3} [h_1^3 (6_1 - 6_2) + h_2^3 \underline{b}_2 + \underline{h}_1^3 \underline{b}_1]. \quad (\text{IX})$$

$$3d. \quad I = \frac{1}{3} [h_1^3 (\underline{b}_1 - \underline{b}_2) + h_2^3 \underline{b}_2 + h_3^3 (\underline{b}_1 - \underline{b}_2) + \underline{h}_2 \underline{b}_2]. \quad (\text{X})$$

$$4th. \quad I = \frac{1}{3} [h_1^3 (\underline{b}_1 - \underline{b}_2) + h_2^3 (\underline{b}_2 - \underline{b}_3) + h_3^3 \underline{b}_3 + \underline{h}_1^3 (\underline{b}_1 - \underline{b}_2) + \underline{h}_2^3 (\underline{b}_2 - \underline{b}_3) + \underline{h}_3^3 \underline{b}_3] \quad (\text{XI})$$

A numerical example of the 4th proposition, formulæ VII and XI, is given below.



$$y = \frac{(10\frac{1}{4} \times \frac{1}{2}) \times (\frac{1}{2} (\frac{1}{2})) + (1\frac{1}{4} \times 4\frac{1}{2}) \times (\frac{1}{2} (4\frac{1}{2}) + \frac{1}{2}) + (\frac{1}{4} \times 31) \times (\frac{1}{2} (31) + 4\frac{1}{2} + \frac{1}{2}) + (1\frac{1}{4} \times 3\frac{1}{2}) \times (\frac{1}{2} (3\frac{1}{2}) + 31 + 4\frac{1}{2} + \frac{1}{2}) + (8\frac{1}{4} \times \frac{1}{2}) \times (\frac{1}{2} (\frac{1}{2}) + 3\frac{1}{2} + 31 + 4\frac{1}{2} + \frac{1}{2})}{10\frac{1}{4} \times \frac{1}{2} + 1\frac{1}{4} \times 4\frac{1}{2} + \frac{1}{4} \times 31 + 1\frac{1}{4} \times 3\frac{1}{2} + 8\frac{1}{4} \times \frac{1}{2}}$$

$$y = \frac{5\frac{5}{8} \times \frac{1}{4} + 5\frac{5}{8} \times 2\frac{3}{4} + 7\frac{3}{4} \times 20\frac{1}{2} + 4\frac{3}{8} \times 37\frac{3}{4} + 4\frac{1}{8} \times 39\frac{3}{4}}{5\frac{5}{8} + 5\frac{5}{8} + 7\frac{3}{4} + 4\frac{3}{8} + 4\frac{1}{8}}$$

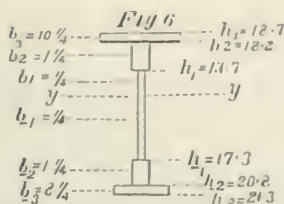
$$y = \frac{1.28 + 15.47 + 158.88 + 165.16 + 163.97}{27} = 18.695$$

A tabular method of computing formula (VII) is as follows:

$b_1 h^i = 10\frac{1}{4} \times \frac{1}{2} = 5\frac{1}{8}$	$\frac{1}{2} h^i$	$= \frac{1}{4} \times \phi b h = 1.28$	
$b_2 h^{ii} = 1\frac{1}{4} \times 4\frac{1}{2} = 5\frac{3}{8}$	$\frac{1}{2} h^{ii} + h^i$	$= 2\frac{3}{4}$	" = 15.47
$b_3 h^{iii} = \frac{1}{4} \times 31 = 7\frac{3}{4}$	$\frac{1}{2} h^{iii} + h^{ii} + h^i$	$= 20\frac{1}{2}$	" = 158.88
$b_4 h^{iv} = 1\frac{1}{4} \times 3\frac{1}{2} = 4\frac{3}{8}$	$\frac{1}{2} h^{iv} + h^{iii} + h^{ii} + h^i$	$= 37\frac{3}{4}$	" = 165.16
$b_5 h^v = 8\frac{1}{2} \times \frac{1}{2} = 4\frac{1}{8}$	$\frac{1}{2} h^v + h^{iv} + h^{iii} + h^{ii} + h^i$	$= 39\frac{3}{4}$	" = 163.97
27		504.76	

$$504.76 \div 27 = 18.695.$$

Adopting this position 18.7 for $\overline{yy}$ we have:



Substituting these values in equation (XI)

$$I = \frac{1}{3} [(13.7)^3 \times (\frac{1}{4} - 1\frac{1}{4}) + (18.2)^3 \times (1\frac{1}{4} - 10\frac{1}{4}) + (18.7)^3 \times 10\frac{1}{4} + (17.3)^3 \times (\frac{1}{4} - 1\frac{1}{4}) + (20.8)^3 \times (1\frac{1}{4} - 8\frac{1}{4}) + (21.3)^3 \times 8\frac{1}{4}]$$

$$I = \frac{1}{3} [(13.7)^3 \times -1 + (18.2)^3 \times -9 + (18.7)^3 \times 10\frac{1}{4} + (17.3)^3 \times -1 + (20.8)^3 \times -7 + (21.3)^3 \times 8\frac{1}{4}]$$

$$I = \frac{1}{3} [2,571 \times -1 + 6,029 \times -9 + 6,539 \times 10.25 + 5,178 \times -1 + 8,999 \times -7 + 9,664 \times 8.25]$$

$$I = \frac{1}{3} [6,539 \times 10.25 + 9,664 \times 8.25 - (2,571 + 6,029 \times 9 + 5,178 + 8,999 \times 7)]$$

$$I = \frac{1}{3} [67,025 + 79,728 - (2,571 + 54,261 + 5,178 + 62,993)]$$

$$I = \frac{1}{3} [146,753 - 125,003] = \frac{1}{3} [21,750] = 7,250$$

In the actual practice of making up the computation of the above formula the following method was adopted :

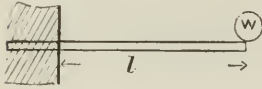
ϕb	3d power of $h \times$ by ϕb	—	+
$b_1 - b_2 = \frac{1}{4} - 1\frac{1}{4} = -1$; $h_1 = 13.7$	2,571	2,571	
$b_2 - b^3 = 1\frac{1}{4} - 10\frac{1}{4} = -9$; $h_2 = 18.2$	6,029	54,261	
$b_3 = 10\frac{1}{4}$; $h_3 = 18.7$	6,539		67,025
$b_{-1} - b_{-2} = \frac{1}{4} - 1\frac{1}{4} = -1$; $h_{-1} = 17.3$	5,178	5,178	
$b_2 - b_{-3} = 1\frac{1}{4} - 8\frac{1}{4} = -7$; $h_{-2} = 20.8$	8,999	62,993	
$b_{-3} = 8\frac{1}{4}$; $h_{-3} = 21.3$	9,664		79,728
		125,003	146,753
			125,003
			3) 21,750
			7,250

For convenience in the application of the foregoing formulæ the following additional ones relating to the strength of beams are quoted.

Let W = the load on a beam in pounds, l = its length in inches,

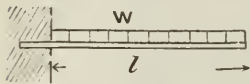
f = the strength per square inch (either in tension or compression) of the material employed, then :

For a beam fixed at one end and loaded at the extreme end with a load = W



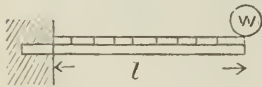
$$\frac{Wl}{f} = \frac{I}{y} \quad (\text{XII})$$

For a beam fixed at one end with load uniformly distributed on its length = W , when $w l = W$



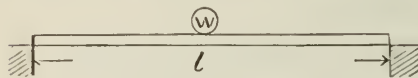
$$\frac{W \frac{l}{2}}{f} = \frac{I}{y} \therefore \frac{w \frac{l^2}{2}}{f} = \frac{I}{y} \quad (\text{XIII})$$

For a beam fixed at one end with a load uniformly distributed on its length = w , and an additional load = W at its extreme end



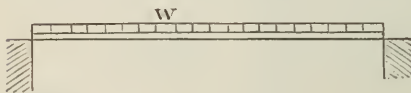
$$\frac{Wl + w \frac{l^2}{2}}{f} = \frac{I}{y} \quad (\text{XIV})$$

For a beam supported at both ends with a single load = W in the middle of its length



$$\frac{W \frac{l}{4}}{f} = \frac{I}{y} \quad (\text{XV})$$

For a beam supported at both ends with load uniformly distributed on its length = w , when $w l = W$



$$\frac{W \frac{l}{8}}{f} = \frac{I}{y} \therefore \frac{w \frac{l^2}{8}}{f} = \frac{I}{y} \quad (\text{XVI})$$

For a beam supported at both ends with a load uniformly distributed on its length = w , and an additional load = W in its middle



$$\frac{W \frac{l}{4} + w \frac{l^2}{8}}{f} = \frac{I}{y} \quad (\text{XVII})$$

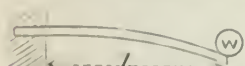
Other conditions must be computed for, but most cases can be considered, approximately at least, by the above.

A suddenly applied load must be considered as exerting double the force of a permanent pressure. The affect of a rolling load, like that

of a railway train, being intermediate with that of a permanent and a suddenly applied load.

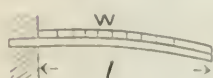
The deflection of beams under loads may be computed in the following cases when s = deflection and E = modulus of elasticity of the material.

Beams of uniform cross section.—For a beam fixed at one end and loaded at extreme end with a load = W



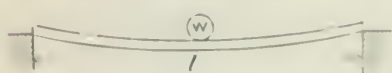
$$s = \frac{1}{3} \frac{W l^3}{E I} \quad (\text{XVIII})$$

For a beam fixed at one end, uniformly loaded



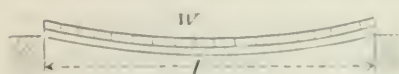
$$s = \frac{1}{8} \frac{W l^3}{E I} \quad (\text{XIX})$$

For a beam supported at both ends, loaded in middle



$$s = \frac{1}{48} \frac{W l^3}{E I} \quad (\text{XX})$$

For a beam supported at both ends, uniformly loaded



$$s = \frac{5}{384} \frac{W l^4}{E I} \quad (\text{XXI})$$

Other cases of deflection become too complicated to be presented in this attempt to give a practical form to these computations.

Railway in Palestine.—A French company has secured the privilege of constructing a railroad in the interior of Palestine. It may be valuable for strategic purposes, and it will undoubtedly develop the commercial resources of the country. The greatest obstacle to the introduction of factories and workshops has been the want of fuel. Egypt, Syria and the coasts of the Red Sea are destitute of wood, and the imported coal commands from 150 to 200 francs (\$30 to \$40) a ton. The asphalt of the Dead Sea indicates probable subterranean deposits of fossilized vegetable matter, and evidences of inexhaustible beds of lignite have been found. The lignite and asphalt can be easily combined in briquettes, at a cost of from 12 to 25 francs (\$2.40 to \$5.00) per ton.—*Les Mondes*. C.

ON THE CORROSION OF PLATE-IRON FEED WATER HEATERS FOR STEAM-BOILERS.

A Note presented by Messrs. Auguste Scheurer-Kestner and Charles Meunier-Dolfus to the "Industrial Society of Mulhouse" at its sitting of May, 1871.

Translated by Chief Engineer ISHERWOOD, United States Navy.

The articles published in the Bulletins of the Industrial Society during several years, and particularly the report made in 1862 by Mr. Burnat of experiments with different boilers, led to the extensive use of feed water heaters placed in the brick flue through which the gases of combustion proceed from the boiler to the chimney. Unfortunately the well-established benefit of these heaters, as regards economy of fuel, is diminished in certain cases by their very rapid destruction.

We propose in the note which we have now the honor of presenting to the Industrial Society to state the causes of this rapid destruction, and the experiments we have made for removing or, at least, diminishing them.

The heaters are subjected to causes of destruction more powerful than those which attack the boiler itself, for although they escape the danger resulting from the contact of the metallic surface with the furnace flame, they are nevertheless more quickly destroyed than are the parts of the boiler the most exposed to the fire. Our remarks apply exclusively to plate-iron heaters, and not to those of cast iron which, owing to the nature of the latter metal, better resist the chemical action.

The object of employing a heater is to reduce the temperature of the gases of combustion to the lowest limit compatible with a sufficient chimney-draft, so that no more heat may escape with them than is indispensable for their necessary ascensional velocity. The cooling of these gases, however, is sometimes thus carried below the point intended,* when it acts injuriously.

1st. By the too great diminution of the draught.

2d. By the deterioration of the metallic surfaces of the heater.

We have nothing special to add to what is already well known

* We have found the temperature of the gases of combustion when leaving the heater to be sometimes below 212° Fahrenheit.

regarding the disadvantages of an insufficient draught. We will merely remark that the use of a heater not only reduces the draught by the resulting lessened temperature of the gases of combustion, but far more by the several right-angled turns it causes in the flue containing it, and by the friction of these gases on its surfaces and on those of the flue.

The deterioration of the metallic surfaces of boilers takes place on the inside and on the outside, but the chemical agents which act on them have not much strength. This is not the case, however, with the heaters, which are exposed to corrosion interior and exterior, with the further danger of being burnt if, through bad design, masses of air or vapor collect in them at different points, as often happens at the bends joining the pipes of the heater or connecting it with the boiler. The communication between two pipes of a heater should be so made that the semicircular bend or connecting part commences at the highest point of the lower pipe and ends at the lowest point of the upper pipe; in the same manner, the connection joining the heater to the boiler should start from the highest point of the upper pipe of the heater.

INTERIOR CORROSION.

The destruction of the iron of the interior surface of a heater is a phenomenon of oxidation; *the iron rusts*: that is to say, it combines with oxygen and is transformed into oxide of iron. This oxygen is not obtained from the decomposition of the water, but from the air which the water holds in solution: and the oxidation is so singularly promoted by the presence of carbonic acid that the rapidity of the corrosion has been found to depend on the nature and quality of the water.

When a heater is examined after several months' use with water made corrosive by the presence of carbonic acid, the interior surface is found covered with a thick coat of ochrous powder forming mushroom-like appearances. The rivets seem to be more attacked than the plate-iron, and their heads are sometimes entirely rusted off while the plate-iron is affected to the depth of only the $\frac{4}{1000}$ of an inch. This ochrous powder effervesces with acids, and contains a mixture of carbonate and of oxide of iron, a composition that well corresponds to the mode of its formation as described above.

Why is not this corrosion observed or, at most, to only a very small extent, in the interior of the boiler? Because this particular kind of

attack on the iron is not made at high temperatures, and results from the fact that the dissolved oxygen alone acts while the water is simply its vehicle. The feed water on entering a boiler in operation is immediately raised to a temperature at which the dissolved oxygen disengages and ascends into the steam room, where it is harmless. In a heater, on the contrary, the feed water is so slowly raised in temperature that its dissolved oxygen can act on the iron; the water in its passage through the heater does indeed lose this oxygen, but, instead of escaping with the steam, it combines with the iron, which it transforms to rust. This is the reason why those parts of the heater that are the farthest from the boiler and the nearest to the check-valve are the most attacked, and why the parts that precede them are less and less attacked as they are nearer and nearer to the boiler.

The nature and quality of the water have a considerable influence on the rapidity of these phenomena of oxidation. Calcareous water which, on losing its carbonic acid, precipitates its carbonate of lime, is accompanied by a slower oxidation; the calcareous salts, by settling on the metal, cover it with a protecting coat that shields it from an interior attack; thus, the earthy matters which are so injurious to the boiler are the preservation of the heater, while the non-calcareous water that spares the boiler destroys the heater by oxidation. The water from the hot-well of engines, when not earthy, forms the best feed for the preservation of boilers, because it has been deprived by its elevated temperature of a portion of its dissolved carbonic acid and oxygen; but if it be calcareous or magnesian, the fatty matter derived from the lubrication of the cylinders, by mingling with those salts, often causes fatty-earth precipitates upon the metallic surfaces of the boiler, and exposes them to being burnt if the temperature is sufficiently high at such places.

The following experiments, which we made with three kinds of water, show strikingly their mode of action upon iron. Three flasks, containing 610 cubic inches each, were filled with three kinds of water to be tried.

The first contained water from the granite rocks of the valley of Saint Amarin, free of calcareous salts but well aerated.

The second contained calcareous water from Jurassic earth, equally well aerated and containing carbonic acid.

The third contained distilled water, recently boiled to expel all the oxygen.

The flasks having been filled to the neck, and the usual precautions in such cases having been taken for preventing the contact of air with the water in the third flask, they were closed by cork stoppers so as to leave no space between the water and the stoppers. Through the centre of the cork stopper a clean and polished iron wire was forced until it touched the bottom of the flask. The stoppers being now sealed, the three flasks were left for several weeks, and the following are the observations made :

Flask No. 1 (water not calcareous) showed the commencement of oxidation. Some yellowish strips or striae soon formed ridges on the bottom of the flask by running down from the wire, which little by little became covered with rust resembling mushrooms in appearance. When all the oxygen of the water was consumed the phenomena of oxidation ceased ; and the wire withdrawn from the flask, cleaned and replaced, remained bright as if it was varnished.

Flask No. 2 (water calcareous) showed the same phenomena of oxidation, but they appeared much more slowly, and the yellowish striae were mixed with the white striae of the precipitated calcareous salts. At the end of some time, the wire having been withdrawn, cleaned and replaced, was again covered with a fresh coat of ochre. The calcareous salts, by their deposition upon the metal, had opposed and retarded its oxidation.

Flask No. 3 (distilled water free of air) showed no phenomena of oxidation. The wire remained bright in it.

These experiments require no commentary, and they give an exact idea of what occurs inside of heaters.

EXTERIOR CORROSION.

The gases of combustion destroy the iron of the exterior surface of heaters. These gases contain the vapor of water and the vapors of the compound acids, of which the sulphurous and sulphuric form the principal portion.* As long as there is no condensation on the metallic surface the acids are harmless, experience having shown that hot acids, even in the presence of aqueous vapor, have but little or no action on

* The gaseous products of the combustion of coal contain a considerable quantity of aqueous vapor. Coal containing from four to five per centum of hydrogen produces by its combustion from thirty-six to forty-five per centum of its weight of aqueous vapor, which is carried along with the smoke. The hygroscopic water of the coal also adds to this vapor.

iron raised to a certain temperature. This is also the reason why these gases and acid vapors have so little effect upon the shell of the boiler. The pipes of the heater nearest the boiler suffer a little more, but the cold ones farthest removed are quickly attacked. The latter become covered with drops of the water of condensation in which the sulphurous acid dissolving in the presence of iron changes to sulphuric acid that attacks the metal.

When a heater is examined which has been in use during several months, yellow crusts, composed of very basic sulphate of iron and oxide of iron, are found upon its outside surface. The attack on the exterior surface takes place especially at the angles and edges of the plate-iron where water can lodge.

As the interior corrosion was greatly influenced by the quality of the water, so the rapidity of the exterior corrosion depends on the quality of the coal. Coal containing large quantities of sulphur causes a very prompt destruction of the outside surface of the heater; while, on the contrary, coal free of sulphur leaves it nearly intact. Although coal contains generally but little sulphur, yet the influence of the resulting sulphurous acid in its gases of combustion has been remarked under other circumstances. One of our colleagues, Mr. Bruckner, two years ago called attention to the formation of sulphate of alumina on the tiles of our manufactories, the sulphur element of which could have been furnished only by the gases of combustion escaping from their chimneys.

The condensation on the other metallic surfaces of the heater, and consequently their corrosion, depends much less on the temperature of the gases of combustion in contact with them than on that of the water in contact with the inner surfaces; and although in practice there is a nearly constant proportion between these temperatures, yet the condensation is almost always accompanied by a considerable cooling of the gases; nevertheless, the condensation of the aqueous vapor can take place even in the mass of hot gases by reason of the heat-conductibility of the iron. If a heater contains cold water, its exterior surface, though immersed in a very hot atmosphere, will have a temperature differing but very little from that of the water; consequently, condensation always takes place on the surface enclosing the water. Some years since Mr. Henri St. Clair Deville made an experiment that throws light on the action of a metallic surface placed between a cold liquid and a hot gas. Having coated the exterior of a platinum tube

with the tincture of turnsol, he passed a rapid stream of water through it and plunged it in the midst of a gas heated to the temperature of bluish-red; the tincture of turnsol, which decomposes at the temperature of 392 degrees Fahr., remained intact.

It thus appears that the corrosion of the exterior surfaces of heaters is principally induced by the low temperature of the water within them, and as the same conclusion applies to the corrosion of the interior surfaces, we have an explanation why the heater is attacked so much more promptly than the boiler.

We will now cite some cases which have fallen under our observation, in order to give an idea of the extent of the injury that can be produced, and will then relate the experiments we have made for the purpose of finding a remedy.

The factory of Mr. Kestner, at Thann, contained six heaters,* having three returns of the current of the gases of combustion which flowed in an opposite direction to that of the water in the heaters; the feed-water was constantly cold, and the temperature of the gases of combustion on emerging from the heaters varied from 194 to 320 degrees Fahr. This apparatus was erected in December, 1866, and was worked day and night. In February, 1869, the two lower pipes of the heaters required repairs. They were greatly corroded on the inside and outside, while, in certain parts, particularly at the joints, the metal had lost 0.008 of an inch of its original thickness. The upper pipes were but little affected. In the lowest pipe the water had a mean temperature of 59 degrees Fahr., and in the next lowest of 86 degrees. The third pipe above the lowest contained water at 104 degrees Fahr. and was much less attacked. The fourth, with water at 122 degrees was scarcely affected. It is remarkable to find theory confirmed in this manner on such a point, for it is known that water between the temperatures of 104 and 122 degrees Fahr. loses the oxygen held in solution.

The exterior corrosion follows the same gradation and appears much diminished in a heater containing water at 104 degrees Fahr.

By feeding boilers, therefore, with water previously heated to 86

*These six heaters were connected to two boilers. During a certain time only one of the boilers being in use and all the heaters being used with it, there was a very rapid destruction of the interior and exterior surfaces of the heaters, notwithstanding the small consumption of coal, which was only 1984 pounds of Roubaix per day and 1322 pounds per night.

degrees Fahr., as is the case with that which comes from the hot-well of steam engines, the chances of the destruction by corrosion of the interior and exterior surfaces of heaters are considerably diminished.

The number of pipes composing heaters increases their chances of corrosion. We have seen that cold water fed to boilers remains harmless, because being immediately heated by mixture with great quantities of water at a high temperature, its dissolved oxygen is disengaged and passes off with the steam. Now if a heater, instead of being formed of six pipes, in which a mixing of the hot and cold waters is not possible, was formed of only one or two pipes, a mixing could evidently take place in it, and a great part of the oxygen, if not the whole, would be disengaged in the gaseous state. But in this case, care must be taken to provide the pipes with such outlets as would prevent the collection of gaseous matter in their upper parts which would expose the metal to burning by the hot gases of combustion.

Two heaters erected in the factory of Mr. Kestner in 1862, and connected with two boilers, have been in use day and night during six years without repairs. Although the water in the lower pipe was at 104 degrees Fahr., yet, at the end of this time, the interior and exterior corrosions were so deep that it had to be renewed. In these two heaters, whose duration was double that of the one previously described, the cold water was always mixed with a large quantity of water at 104 degrees Fahr., from which resulted a diminution of the destructive action of the water, and also of the condensation on the exterior surfaces.

Similar facts have been observed during several years in other factories. "The Alsatian Association of the owners of steam boilers" have renewed twenty heaters in a single year. The age of these apparatus varied from five to eight years of day service.

We have attempted the protection of the interior metallic surfaces of the two lower pipes of heaters by the application of paint or tar. This diminished the corrosion which may possibly be prevented by constant renewal of the coating.

With the view of protecting the heaters against exterior corrosion, we have tried the application of paint to the outside of the lower tubes, but it did not resist the acid condensation nor the heat of the gases. We succeeded better by tinning part of one of the lower tubes. After remaining six months in the flue, the tinned part of this tube, in which the temperature of the water was never higher than 86 degrees Fahr.,

was found perfectly preserved. The temperature of the gases of combustion, when emerging from this heater, never exceeded 392 degrees Fahr.

Finally, considering the great disadvantages of plate iron when its opposite surfaces are exposed to the action of cold water and an acid atmosphere, we experimented with copper. Another part of the heater was encircled by a band of copper 0.008 inch thick, closely applied with its edges bolted together. After six months it was found pierced by corrosion with innumerable holes and transformed in great part into basic sulphate of copper. Under these conditions, the copper did not resist the action of the sulphurous Ronchamp coal.

From the preceding facts appear that the remedy for the evils resulting from too cold a feed-water or from too great a cooling of the smoke, is the painting of the interior surfaces of the lower pipes * of the heater and the tinning of their exterior surfaces.

In the manufacture of new heaters, designs should be adopted which admit the use of cast iron instead of plate iron, as cast iron better resists the action of gaseous acids. We have observed those cast iron bends of the heaters which are not covered by the masonry, and are therefore exposed to the gaseous current, are vastly less attacked than the plate iron. The difference is due to two causes: first, the nature of the metal itself; second, its greater thickness, which by keeping the exterior surface at a higher temperature render the condensation less copious. A long experience confirms this opinion, for cast iron heaters erected many years ago in Alsace have resisted the influences we have described.

Be that as it may, the advantage of even plate iron heaters of large diameter of pipe, as regards economy of fuel, is much greater than the cost of making and repairing them, in proof of which we need only cite the boilers mentioned above, the heaters of which were in the most favorable condition for destruction, and in the least favorable condition for economic effect by reason of a very small daily consumption of coal.

The consumption of coal having been 647 tons per year (mean of three years), and the economy produced by the heaters eight per

* We are here speaking of only plate iron pipes of large diameter, in which the circulation of the water is methodical.

centum,* we find their annual saving to be 52 tons of coal, or about \$208, at \$4 per ton; the price of three heaters for a boiler being about \$600, the heaters pay for themselves in three years at most. The daily consumption of coal being generally much greater than the above, the saving effected by the heaters will be correspondingly greater, and the cost of their additional heating surface is rapidly recovered by their economy of coal.

ON THE HISTORY OF ALIZARIN AND ALLIED COLORING MATTERS.

Read before the Chemical Section of the Society of Arts, May 22d, 1879,

By W. H. PERKIN, F.R.S.

It will be interesting to inquire into the commercial results of this industry, and, firstly, what has been its influence upon the sale of madder and its derivatives. The annual value of the imports into the United Kingdom of madder and garancine, from 1859 to 1868, amounted to about £1,000,000, with prices averaging for madder 45s. to 50s. per cwt., and for garancine, 150s. In the subjoined table will be seen the remarkable changes that have taken place in the imports, and also the great reduction in price:

Average Annual Imports of Madder and Garancine into the United Kingdom and prices.

Year.	Madder. cwts.	Garancine. cwts	French Madder.	Turkey roots.	Garancine.
1859 } 1868 }	305,840	45,560	45s.	50s.	150s.
1875	100,280	25,860	—	—	—
1876	59,137	15,396 or 6,436 }	—	—	—
1877	38,711	8,875	—	—	—
1878	32,990	2,790	18s.	17s.	65s.

*The economy of these heaters has been determined not only by observation of the elevation of temperature they produce in the feed-water, but also by comparative experiments on boilers functioning with and without them during periods of several weeks.

Up to and during 1876 considerable quantities of artificial alizarin were imported from the Continent and entered at the Customs as garancine or madder, which, having been brought to the notice of the officials, the returns made subsequently are more reliable. The imports of garancine were returned by the Board of Trade in 1876 as 15,396 cwts. when first published, but in the following year, when the figures for 1876 were given for comparison with those of 1877 and 1878, the returns were stated as only 6,436 cwts. The erroneous entries were most probably made to evade the penalties for the infringement of patent rights.

Dutch ground madder has been relatively much higher in price than the other qualities. This is owing to its extensive use in wool dyeing. For various reasons artificial alizarin has made but little progress in its application to wool dyeing, and Dutch madder being mostly used for this purpose, its prices have been maintained at from 28s. for ordinary "Ombro" to about 40s. to 45s. for crop madder. The wool dyers have, however, been working cautiously with artificial alizarin, and now some of them are using it somewhat largely, and considering its cheapness as compared with Dutch madder, no doubt they will soon find how to use it successfully and cease to employ madder.

The decline in the sale of madder is still rapidly going on. During the first two months of last the year the imports were

Madder,	6,846 cwts.
Garancine,	533 "

During the first two months of this year they were

Madder,	2,185 cwts.
Garancine,	175 "

or about two-thirds less. And not only so, but the price is still declining. Turkey roots may now be bought at 11s. per cwt., whereas before artificial alizarin was introduced they were sold, on an average, at 50s. At the present prices of madder, its cultivation is unremunerative, and will, undoubtedly, be soon a thing of the past. Such has been the success of artificial alizarin in competing with madder and garancine in this country, and it is equally true of other countries. The quantity of madder grown in all the madder-growing countries of the world prior to 1868 is estimated at about 70,000 tons per annum. The amount of artificial alizarin now produced is equal in dyeing power to considerably more than this; in fact, the lowest estimate I

have been able to get for 1878, and which was confirmed from other sources, is 9,500 tons, which is equivalent to 950,000 tons of madder. This remarkable result has been arrived at in ten years only.

To produce this quantity of artificial alizarin, there are about nine manufacturers on the Continent and one in this country, Messrs. Burt, Bolton & Haywood, who have two large works for its production, viz., the original works at Greenford Green, and new ones at Silvertown.

Graebe and Liebermann, in their paper in the *Moniteur Scientifique*, April, 1879, p 416, give some statistics of the production of artificial alizarin which, however, require correcting. They also leave out the years 1869 and 1870. In 1869 we had advanced in the manufacture so far as to send color into the market, the first invoice being dated October 4th, and that year we produced about one ton. In 1870 we produced 40 tons; in 1871, 220 tons; in 1872, 300 tons, and in 1873 435 tons. Up to the end of 1870 we were practically the only makers of this product. One of the largest chemical and coal tar color manufacturing firms of Germany, with whom we were in correspondence, stating that in November, 1870, they had only lately commenced producing 50 lbs. of alizarin, 10 per cent. quality, per day, and that no one else in that country was supplying artificial alizarin, and in 1871 we were practically the only producers of quantity, at any rate during the first part of the year, for in March, 1871, the firm already referred to, and who had great opportunities of knowing what was being done in their country, wrote that they had not received knowledge of any establishment but their own manufacturing artificial alizarin.

In November, 1871, however, Messrs. Gessert Frères announced to the Industrial Society of Mulhouse that they had produced 30,792 kilogrammes of alizarin in paste. This is equal to about 30 tons, an amount which was evidently considered by them a very large quantity.

Graebe and Liebermann's statistics are as follows compared with our production :

	Graebe and Liebermann. Tons.	Perkin & Sons' Production. Tons.
1869, ...		1
1870, ...		40
1871, ...	125-150	220
1872, ...	400-500	300
1873, ...	900-1,000	435

Without wishing to detract from Graebe and Liebermann's original discovery, we may say that the birthplace of the manufacture of artificial alizarin was in England. It was in this country that the difficulties and doubts about the manufacture and supply of the raw material, anthracene, were solved, and the production of artificial alizarin by new processes successfully accomplished. After these results were obtained in this country, Continental chemists were encouraged to manufacture on a comparatively large scale, but up to the end of 1873 the English manufacturers had practically no competition in the home market. Having considered the amount of artificial alizarin now manufactured, it will be of interest to see what its money value is.

Taking the lowest estimate, viz., 9,500 tons, and calculating its selling prices at £150 per ton, the annual value amounts to no less than £1,425,000, or nearly a million and a half.

As a dye, it is now at most not more than one-third of the average price of madder in 1859—1868. Consequently, in the United Kingdom, when the annual value of madder imported was £1,000,000, the annual saving is very great.

While collecting the statistics about alizarin, I thought it would be of interest to get, if possible, the statistics of the entire coal tar color industry, and to the kindness of H. Caro, of the Badische aniline and soda fabrik, I am indebted for most of the following particulars:

Estimated Value of the Production of Coal Tar Colors in 1878.

Germany,	£2,000,000, of which four-fifths are exported.
England,	450,000
France,	350,000
Switzerland,	350,000
Total,	£3,150,000

There are now in this country six coal tar color works; in Germany no less than 17; in France about 5, and in Switzerland 4. There are also three works in Germany and three in France which manufacture aniline in enormous quantities for the production of coal tar colors.

Such is the wonderful growth of this industry, which dates only from 1856. It is the fruit of scientific researches in organic chemistry, conducted, mostly, from a scientific point of view; and, while this industry has made such great progress, it has, in its turn, acted as a handmaid to chemical science, by placing at the disposal of chemists

products which otherwise could not have been obtained, and thus an amount of research has been conducted through it so extensive that it is difficult to realize, and this may, before long, produce practical fruit to an extent we have no conception of. One very important coloring matter related to coal tar, and one of the original sources of aniline—a product of as great importance as alizarin—has yet to be produced on the large scale. I refer to indigo. Baeyer has shown that it can be produced artificially, but at present no practical means of accomplishing it have been discovered. No doubt, however, it will not be many years before this is achieved, and the cultivation of the indigo plant share the fate of madder.—*Journal of Applied Science.*

ROAD MAKING.

By M. JULES LAFFINEUR.

Translated and abridged from the *Annales du Génie Civil* by PLINY E. CHASE, LL.D.

A ballasted road, in good condition, should present a smooth, hard and compact surface, and should form an impermeable covering for the soil upon which it rests; consequently the two qualities to be considered in the materials which compose it are hardness and facility of uniting. Although the union of these two qualities is very valuable, it is far from being always indispensable.

The hardness of the materials presents a very great advantage only for the composition of the upper layer, which is designed to support the direct action of the wheels. As to the lower layer, which, in a good system, ought never to be reached by the wheels of the carriages, it is sufficient that it should be formed of yielding materials, in order to be able to intercept the communication with the soil and to shelter it from atmospheric influences.

As to the size of the ballasting, experience has shown that the most suitable dimension is that of six centimetres (2.36 inches) diameter. It is not necessary that all the pieces should have a uniform size; even if this were possible it would be far from being advantageous. The upper limit should be six centimetres, and there should be fragments of various other dimensions, so that the smallest can lodge in the spaces between the largest, and thus form a mass more compact and

less movable. If the ballasting is very hard, the diameter of six centimetres may be somewhat too great, even for the largest pieces.

When a road has been built after this system, it is far from being immediately fit for traveling, on account of the great amount of draught which it requires. The materials being simply laid against one another, the wheels easily separate them and rapidly produce ruts in which they can move only with extreme difficulty. The travel does not become easy until the prolonged passage of carriages, aided by atmospheric influences, has consolidated the materials, so as to form a compact and resisting mass.

When this consolidation is effected solely by the traffic, it is accomplished slowly, in an irregular manner, and with great loss of force, provided the force is left to act by chance and without any determinate direction. Therefore, roads should not be opened to the public until they are ready for immediate use and they present the least possible resistance to draught. The simplest means of artificially arriving at this result is to use a very large and heavy compressing roller. The roller, however, can never effect so complete a union as is established by long travel. There is probably a chemical action for which time is an indispensable requisite, and for which there is no possible substitute.

When a road has been constructed in accordance with these principles and processes, it should present the maximum of solidity with the minimum of thickness and, consequently, with the minimum of cost. If this thickness appears small in comparison with the one which is generally adopted, it is compensated by the compact and unalterable mass which it forms. In a causeway, for example, with the thickness of 15 centimetres (5.9 inches), if trenches are cut after the road has been for a long time in use, this normal thickness of 15 centimetres will be found everywhere, forming a perfectly compact whole. On the contrary, in a causeway with a thickness of 25 centimetres (9.843 inches), built with materials which are freed from all foreign substances, and consolidated by the travel and by successive additions of ballasting, instead of finding the uniform thickness of 25 centimetres, there will be sometimes 30, sometimes 15, and sometimes only 5 centimetres. Moreover, there will always be a mixture, more or less considerable and often enormous, of detritus, having no union with the larger ballasting; so that such a road, after having used much more ballasting than the former, and having imposed upon the travel a burden ten times as great, will present much less solidity. In the true system there is

not a stone lost, everything concurs to a useful end, and we obtain the best result with the greatest economy of means.

The defects of the common system are manifested to every observer by the great number of permanent and temporary road laborers that are employed. The methods of maintenance which constantly secure solid road-beds reduce the waste to the simple wear of friction and consequently to a minimum. They are the methods which require the least repair and the least expense. In order to maintain a road in perfect order, it is necessary to stop the slightest dilapidations at the outset, and even to prevent their development. The most rational method requires three principal operations :

1. To facilitate the rapid escape of rain-water or of other things which ought never to remain upon the road.
2. The removal of the detritus produced by the wear of traffic as speedily as possible.
3. The prompt application of the materials which are required for repairs.

If the roads have the form which has been indicated, the discharge of the water will be accomplished naturally and easily, without the aid of manual labor, or with occasional slight and inexpensive assistance.

The removal of the detritus may be accomplished at intervals more or less frequent, either in the form of mud or of dust, with different instruments, the principal of which are the rake and the broom. The waste should never be allowed to remain too long upon the road. Mud is always injurious ; it maintains a moisture which softens the road and disturbs the whole organization. It hastens the formation of ruts and increases the draught of carriages. Dust is hardly less injurious ; it increases the draught, and at the first rain forms mud with all its inconveniences. The removal of the waste should be uninterrupted, and since, in such case, there can never be any great accumulations, the rake and broom will be sufficient.

Roads which are carefully watched, maintaining a sound surface, with very slight depressions, the ballasting requires especial care. The stones should be broken finer than those which are designed for new roads, and only enough should be employed to restore the normal thickness and replace the wear. It should be used only in moist weather, when the road-bed is a little softened. In order to facilitate the adhesion of the ballasting to the old road-bed it is well to indent

the borders and even the whole surface of the new ballasting and to cover it with some of the waste, unless there is considerable quarry gangue. These precautions would always maintain smooth and hard surfaces, nearly free from mud in winter and from dust in summer. They would lead to great savings in the supply of ballasting and in the employment of laborers. The work of the regular laborers should be limited to the simple care of the road-bed. All other work, such as the maintenance of ditches, slopes, sidings, etc., should be done by contract or given out in jobs to special laborers.

CHEMICAL COMPOSITION OF MINERAL COAL.

Abridged from *Comptes Rendus* by PLEISY EARLE CHASE, LL.D.

For nearly thirty years Prof. E. Fremy has been studying vegetable tissues, with especial reference to the chemical nature of the principles which they contain, and the influences which have changed them into lignite, bituminous coal and anthracite. He began with examining the vegetable skeletons. The substances which he first studied were almost wholly unknown; their characteristic property is their production, under the influence of a ferment or of reagents, of gums and gelatines. He showed that they are all derived from a primitive insoluble compound, which he called *pectose*, represented in its greatest simplicity by the formula $C_5H_5O_7$, and which, by successive polymeric transformations, forms at first gummy substances, then gelatinous bodies, and finally an acid soluble in water.

He then began the study of the stable elements which form the fibres, cells and vessels. He found that the vegetable frame-work is not so simple as he thought; it is not built up of simple cellulose, differently incrustated by other substances, but of many kinds of isomeric cellulose. There is also, in nearly all parts of the skeleton, a very important body, which differs from the celluloses in composition and properties, which abounds in the vessels, and which he therefore calls *casculose*. The proportions in which it exists in different kinds of wood, affect their physical qualities. Oak may contain 30 per cent.; in walnut shells there is sometimes 50 per cent. It binds the woody fibres together. Caustic alkalis dissolve it, and they are therefore employed in the manufacture of wood paper.

After ascertaining the composition of the internal tissues, he analyzed the cuticle and other coverings, discovering *cutose*, which is well fitted, by its resistance to chemical change, for protecting the parts which are exposed to the air.

Passing, next, to the bodies which are most often found in the tissues, he showed that gum is a true salt of lime, and that chlorophyll owes its green color to a salt of potash.

In extending his studies to combustible fossils, he first sought what chemical differences characterized wood, peat, the different lignites, bituminous coal and anthracite. He found that wood is not sensibly attacked by a dilute solution of potash, while peat often yields to that alkali considerable quantities of ulmic acid; xyloid lignite, or fossil wood, still contains notable proportions of ulmic acid, but it is easily distinguished from wood and peat, because it is changed into yellow resin by nitric acid and it is completely soluble in hypochlorites; compact, or perfect lignite contains no appreciable ulmic acid, and still it is dissolved in nitric acid and the hypochlorites; as to the true coals, they are characterized by their insolubility in neutral solvents, acids, alkalies and hypochlorites.

In his synthesis, he was guided by the experiments of Daubrée and Baroullier, which indicated the importance of heat and pressure in coal metamorphosis. He performed a series of experiments, in which vegetable tissues and the substances which most often accompany them in organization, were separately kept, for a considerable time, at temperatures from 200° to 300° (392° to 572° F.), in hermetically sealed glass tubes. He found that cellulose, vasculose and cutose all became black, brittle, yielding water, acids, gas and tar, but preserving their organization; they did not melt, but gave a fixed product which showed no resemblance to mineral coal. With sugar, starch, gum, chlorophyll and the fatty and resinous bodies which accompany it in the leaves, the results were very different. By long calcination under pressure they became black, shining, often melted, absolutely insoluble in the tested chemicals, and very different from charcoal, for when heated to redness they behaved like organic bodies, yielding water, etc., but having, as a fixed residuum, a hard and brilliant coke. The chemical resemblance to a specimen of Blanzý coal, which was analyzed by Regnault, is thus shown:

	Carbon.	Hydrogen.	Oxygen.	Ashes.
Coal from sugar,	66.84	4.73	28.43	
“ “ starch,	68.48	4.68	26.84	
“ “ gum arabic,	78.78	5.00	16.22	
Blanzy coal,	76.48	5.23	16.01	2.28

He was induced to experiment on these three substances because, according to Ad. Brongniart, they must have abounded in the vegetables which produced the coal beds, and because gum often comes from the transformation of tissues, as Trécul has shown.

Further experiments led him to the dominant hypothesis that vegetables are first changed into peat, and that, in that form, the disappearance of the organized tissues is due to a kind of turfy formation, as Van Tieghem suggested. He then operated on three kinds of ulmic acid: 1, acid which he had himself extracted from peat; 2, saccharumic acid, which he obtained from M. P. Thenard; 3, ulmic acid extracted by treating vasculose by alkalis. They were all transformed into substances similar to the foregoing, under the combined influence of heat and pressure, as is shown by the following analysis:

	Carbon.	Hydrogen.	Oxygen.
Coal from peat acid, heated 24 h.,	67.48	5.84	26.68
Same, heated 72 hours,	71.72	5.03	23.25
“ “ 120 “	76.06	4.99	18.95
Coal from vasculose acid,	76.43	5.31	18.26

Finally, he examined the modifications, under heat and pressure, of mixtures of chlorophyll with the fatty and resinous bodies which alcohol extracts from leaves. Although the mixture was at first soluble in alkalis, after 150 hours' treatment it gave a black substance, viscous, insoluble in caustic alkalis, and presenting an evident analogy to natural bitumens.

Alizarin-Carmine.—A new coloring material is manufactured, under this name, by the Austrian Alizarin Manufacturing Company. With tin as a mordant, it dyes wool orange; with alum, red. It is said to surpass all previous dyes of similar tints, in beauty, brilliancy, durability and variety of shading with different mordants, and resistance to change under exposure to light, air, perspiration and washing.
—*Fortschr. der Zeit.* C.

REPORT OF THE COMMITTEE ON SCIENCE AND THE
ARTS ON THE FAIRBANKS TESTING MACHINE.

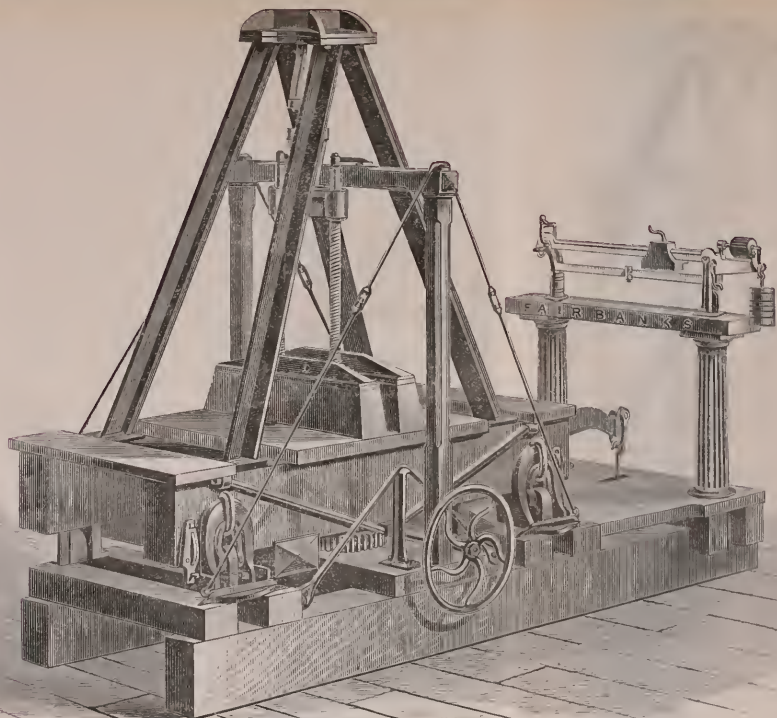
HALL OF THE FRANKLIN INSTITUTE, }
Philadelphia, March 24th, 1879. }

The Sub-committee of the Committee on Science and the Arts, constituted by the Franklin Institute of the State of Pennsylvania, to whom was referred, for examination, Fairbanks' Testing Machine, report that the machine consists of a section of track scale of their usual type, having a platform about 8 feet long by 4 feet wide, resting at its four corners on knife-edges in four multiplying levers. The fulcrums of these levers are supported on knife-edges in links freely suspended in yoke-castings, which are connected together in pairs by transverse wrought iron frames and bolted on a strong, well-braced timber foundation, while the long ends of the levers are connected by means of links and knife-edges with a series of long multiplying levers leading to a graduated beam similar to that of the ordinary platform scale.

This weighing apparatus is excellent, every part being carefully proportioned to the work it has to do, and the whole arrangement being well adapted to insure the greatest accuracy with the least liability to wear or derangement, the only objection to it being the space occupied—12 feet by 6 feet—occasioned by the length of the levers and the openness and simplicity of the construction.

On top of the platform are four inclined cast iron columns supporting a cross-head from which is suspended the wrought iron head with the wedge-shaped clamps for holding one end of the specimen to be tested for tensile strength. The other end of the specimen is clamped in a similar head connected to a cross-head which can be moved up and down by two screws which are supported at their upper ends in bearings bolted to a timber frame-work, and pass down through the platform of the scale to bearings in a strong cross girt between the beams on which the scale rests. The screws are rotated by means of tangent wheels operated by worms on a transverse shaft on one end of which is a pulley with a crank handle. On the other end of this shaft is a large gear wheel worked by a pinion with a similar pulley and crank handle. When motion is given to either of these pulleys, the rotation of the screws draws down the movable cross-head with the clamp holding one end of the specimen, and as the clamp holding the other end is supported by the scale platform, any strain put upon





the specimen will be shown by the beam precisely as if the platform was acted upon by a weight.

When tests for transverse strength are to be made, the specimen is supported on two knife-edges resting on the platform at a definite distance apart, while a central knife-edge on the under side of the movable cross-head is brought to bear upon it by the screws as before.

In testing metals it is essential that the gripe of the wedge clamps on the sides of the specimen shall be uniform and not tighter on one edge than on the other, in order that the strain shall be equal on the entire cross-section and produce no tearing tendency. To effect this, one of the wedges is made rounding on its back and with side play in its seat, so that it can adjust itself to any inequalities or want of parallelism in the specimen.

An ingenious and efficient device is applied to the graduated beam by which the small poise is moved out automatically as long as the beam is up, but stops whenever the beam falls, thus recording the exact point at which the specimen breaks, and enabling one man to make a test with accuracy.

The process of making a test is as follows: After fixing the specimen in place, the heavy poise is set at the notch on the beam at which the specimen is expected to stretch, and the small poise drawn back to zero. The crank on the worm shaft is then rotated until the beam rises, when the small poise commences to move out automatically. At this point it is usual to change to the other crank in order to gain power and to prevent overrunning the motion of the small poise. With care the beam can be kept in a horizontal position with the poise just balancing the strain. When the elastic limit is exceeded, the specimen yields rapidly, the motion of the crank has to be increased, and finally when the specimen breaks, the beam falls, stopping instantly the motion of the poise. The position of the poise then indicates the exact weight which broke the specimen.

We consider this machine accurate and reliable, easy to be understood and manipulated, and with little tendency to wear or to derangement of its parts, and that its design and mode of construction would enable any repairs or renewals to be easily and cheaply made.

WM. H. THORNE.

WM. D. MARKS.

J. HAUG.

L. R. FAUGHT.

JOSEPH ZENTMAYER.

Adopted May 7, 1879.

H. CARTWRIGHT, *Chairman pro tem.*

THE SUN'S COMPOSITION.

At the recent meeting of the Royal Astronomical Society in London, Professor Henry Draper, the distinguished American physicist, brought before an audience of English astronomers and physicists the evidence by which he appears to have demonstrated that oxygen exists in the sun. It will be remembered that when, in 1859, Kirchhoff showed how the dark lines of the solar spectrum enable us to analyze the vaporous envelope of the great central luminary of our system, the substances, the presence of which was recognized, belonged, with one exception, to the family of metallic elements. Iron, zinc, copper, aluminium, sodium, magnesium, cobalt, nickel, calcium, chromium, titanium and manganese were found to be present in the sun. Besides these metals, hydrogen was recognized. It is doubtful whether even hydrogen ought not to be included among the metallic elements, for the late Professor Graham succeeded in forming what he regarded as an alloy of hydrogen and palladium, which (if his interpretation of the experiment was correct) would oblige us to consider hydrogen as a metal no less than palladium. In that case hydrogen would be regarded as a metal which, at ordinary temperatures, is in the gaseous form, precisely as mercury is, at ordinary temperatures, a fluid metal. Adopting this, which is probably the correct view, we may say that all the elements the presence of which in the sun had been determined by dark lines—that is, by absent, or rather by relatively feeble tints—in the solar spectrum are metallic. The absence of all evidence respecting some of the other elements might not have seemed remarkable, because it might well be believed that they were present in quantities relatively so small that our means of analyzing the sun failed to detect these substances. We could thus understand why spectroscopists should have obtained no evidence of the presence of gold in the sun, the element by the way, which the alchemists and astrologers of old times regarded as specially solar. But that such elements as oxygen, nitrogen and carbon, which are such important constituents of our earth, should be absent from the sun, or should not be present in quantities large enough to make their detection easy, seemed surprising. The wonder was increased in the case of the two latter elements by the circumstance that Dr. Huggins recognized the presence of nitrogen in

the faint mist-like objects, the gaseous nebulae, and the presence of carbon (though not quite so satisfactorily) in certain comets. But though no spectroscopic evidence of the presence of oxygen in any of the self-luminous celestial bodies had been obtained, so that the absence of any evidence of oxygen in the sun was in one sense less remarkable, it was in another sense the most remarkable of all the negative results of solar spectroscopic analysis. Oxygen is commonly believed to form one-third of the mass of our earth's crust, and is known to form eight-ninths of the water where it is combined (that is, chemically associated) with hydrogen, and one-fifth of the air where it is mixed (not combined) with nitrogen. We cannot, it is true, assume that the structure of the sun is identical with that of the earth; indeed, many consider that each planet, according to its distance from the sun, is differently constituted, having the same elements, perhaps, but in different proportions, while the sun is unlike them all. Yet it would be difficult to understand how in the great central mass, in which the denser elements would be the more abundant, the lightest of all, hydrogen, should be present in enormous quantities, while oxygen, so much denser under the same conditions, should be absent or present only in such small amount as to afford no evidence of its existence. The natural inference would be that oxygen and the other non-metallie elements, though really present in the sun, are situated below that visible surface of the sun which we call the photosphere. That at any rate they are not present above that surface in any considerable quantity is clearly shown by what happens during total eclipses of the sun; for whereas, at the moment when the sun is just fully hidden by the moon, the metallic elements usually recognized by the absorptive action of their vapors on the sun's light can be recognized by their emissive action, a rainbow-tinted array of bright lines suddenly replacing the rainbow-tinted streak crossed by a corresponding array of dark lines, the bright lines of oxygen, nitrogen, carbon and other non-metallie elements have never been recognized, even under these favorable conditions. But if oxygen existed in enormous quantities within the visible globe of the sun, its presence might be recognized in another way. Besides the dark lines in the solar spectrum, there are bright lines certainly at times, and probably always. Some, indeed, have said that as the glowing vapors which produce the rainbow-tinted array of lines just mentioned, are at all times present over the sun's surface, there are always bright lines; but as the question is always of relative brightness, and

as these particular tints are fainter—corresponding, in fact, to the dark lines—this mode of speaking seems as incorrect as it would be to describe the dull disk of a small red hot globe, seen projected on a bright background at a white heat, as forming a bright instead of a dark spot on that bright white background. When, however, as sometimes happens, the known lines of some element disappear and presently reappear as bright lines, we perceive that for the time being the spectroscopic evidence respecting that particular element is changed in character. We know that that element is present in the part of the sun examined, but we know this because we see the bright lines, not, as usual, the dark lines of that element. This happens frequently, for instance, in the case of hydrogen, when those exceedingly bright parts of the sun's surface, which are called faculæ, are examined. For the time being, the hydrogen there, probably to a depth of many thousand miles below the visible surface, is glowing with a heat exceeding that of the matter forming the photosphere, regarded as a whole; thus, the hydrogen indicates its presence by its emissive, not by its absorptive, action. If oxygen were present in very great quantities in the sun, but always lay below the visible solar surface, and was at a higher temperature than that prevailing at the surface, then oxygen might indicate its presence by its bright lines, and could certainly indicate it in no other way. Now it is evidence of precisely this kind that Professor Draper seems to have obtained respecting this most important element. He had been engaged since 1863 in obtaining simultaneous photographs of parts of the solar spectrum and of corresponding parts of the spectra of hydrogen, nitrogen and carbon. In examining a series of such photographs, in which the fluted spectrum of nitrogen was in juxtaposition with the solar spectrum, he found reason to suspect that some of the bright lines of nitrogen agreed exactly in position with bright bands in the spectrum of the sun. Pursuing his researches, he found, even at that early stage of his labors, very striking evidence of agreement between the bright lines of oxygen and solar bright bands. It was not, however, till the year 1877 that he was so far satisfied as to announce "The Discovery of Oxygen in the Sun." The paper thus named was illustrated by enlarged views of the negatives he had obtained. So that, in point of fact, the reader was provided with the very evidence which had satisfied Professor Draper. He did not merely send pictures of what he had seen, but the observations themselves, seeing that the photographs remained pre-

cisely as nature had left them, save only for a few reference lines and letters added around the margin to make them intelligible. In these photographs a part of the spectrum of the sun was seen side by side with the bright-line spectrum of air. The bright lines of iron were shown in company with those of air, in order to indicate the exact agreement of the juxtaposed spectra by the coincidence of the iron bright lines with the corresponding solar dark lines. Every one of the oxygen bright lines was seen to coincide with a bright part of the solar spectrum. In some cases the coincidence was very striking, because the bright line of the air spectrum not only agreed exactly in position, but very closely in character also, with a bright band in the solar spectrum. This close resemblance could not in every case be recognized—a circumstance by no means surprising when we remember that if these bright bands in the solar spectrum are really due to the presence of great quantities of oxygen below the visible solar surface, the light of this oxygen can only reach us after passing through the cooler envelope of metallic vapors which produces the dark lines, and must be affected by the absorptive action of those vapors, which, of course, was not the case with the oxygen of the air from which Professor Draper obtained the bright-line comparison spectrum.

Many experienced spectroscopists remained unconvinced by the evidence which Professor Draper thus advanced in 1877. They considered that the dispersive power of his spectroscopic battery was not sufficient to place beyond question the coincidences on which he based his conclusions. Other objections also were advanced which need not here be dwelt upon. In the true scientific spirit Professor Draper set to work to apply more searching tests to his result. The scale of his enlarged photograph had been half that of Angstrom's well-known "normal spectrum." Those which he exhibited last Friday at the Astronomical Society were on a scale four times greater. The evidence derived from each coincidence was thus increased four fold in value, the evidences from two coincidences sixteenfold; from three, sixty-four fold, and from the eighteen recognized coincidences about 68,725,000,000 times. He effected also an improvement likely to have great value in other spectroscopic researches. The electric spark through air, which gave the air spectrum, pursued a zigzag course, like a lightning flash on a small scale. He wanted a straight flash, or at any rate a flat flash, as that seen from one direction it should appear as a straight line. So he invented what he calls the spark-compressor. The terminals

between which the spark passes are introduced into a small block of soapstone, and between them a small flat aperture is prepared, between the walls of which the electric flash has to travel. This space is left open on one side, somewhat like the slit of a money-box, and the spark seen from that side necessarily appears as a straight line, though it may have a considerable amount of zigzag play in the plane of the flat space left for its passage. The result of this arrangement is that the spectrum of the air lines—oxygen and nitrogen—as also of the iron lines, obtained by having a little iron at one of the poles, is much better defined and more trustworthy than it had been before this plan was adopted.

It may be interesting to say, in conclusion, a few words about the labor and time involved in this research. The bobbin of the Gramme machine revolves once for each spark used in obtaining the photographs of the air spectrum. Each photograph requires 30,000 sparks, and the photographs obtained in the last three years have required no less than 20,000,000 sparks; so that the bobbin of the Gramme machine has revolved 20,000,000 times. Although the petroleum engine used for driving the machine consumes only a couple of drops of oil at each stroke, 150 gallons have been used up in three years.

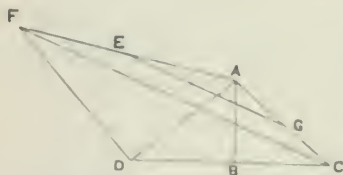
Formation of Hail.—M. G. Oltramare points out two different results which may arise when air that is saturated with moisture becomes chilled. The watery particles may collect in drops and fall by their own weight, leaving the air transparent; or they may remain in suspension and form a cloud. In the latter case he supposes that the molecules are kept apart by electrical repulsion. Jamin and other investigators have found that the watery particles in mists, may remain liquid at -14° , or even at -20° (6.8° or -4° Fahr.), provided there is no sudden shock or solid contact, especially with ice. In such a condition of "superfusion," if there is a sudden discharge of electricity the separating force disappears, and the sudden union of particles, under their joint attractions, forms hail-stones of various magnitudes. This explanation accounts for the rustling which is heard before a fall of hail, as well as for the accompanying electrical phenomena. The size of the stones depends partly on the thickness of the cloud, partly on the lowering of temperature in superfusion.—*Comptes Rendus.* C.

APPROXIMATE QUADRATURES OF THE CIRCLE.—II.

By PLINY EARLE CHASE, LL.D.

Since the publication of my graphic approximation in the July number of the JOURNAL OF THE FRANKLIN INSTITUTE,* my attention has been called to the following construction in Perkins's Geometry (D. Appleton & Co., 1853).

On an indefinite straight line AN , lay off $AB = BD = DE = 1$; at E erect a perpendicular $EG = 2AB = 2EF$; on EN lay off $EH = HK = AG$, KL (towards A) $= AF$, LM (towards N) $= DG$, $MN = DF$; bisect EN at P , EP at R , and AB at C ; trisect ER at T . Then $CT = 3.1415922 \dots$



The author calls his method "very simple," and says that a better one "can hardly be expected, or even desired." But the approximation of Adrian Metius, $\frac{355}{113}$, is still closer, and the following construction of his ratio is

more simple:

On $AB = 7$ erect the perpendicular $BC = 8$; extend CB to D , taking $DB = 9$; on AD erect the perpendicular $DF = 15$; take $AE = AC$ and draw EG parallel to FC . Then $AF = \frac{355}{113} AG = 3.14159292 \dots AG$, the true ratio of the circumference of the diameter being $3.14159265 \dots$. The error of this construction is less than $\frac{1}{1130000}$ of one per cent. Perkins's error is a little more than $\frac{1}{700000}$ of one per cent. Neither method is so simple nor so desirable for practical purposes as the one which was given in the last number of the JOURNAL.

HAVERFORD COLLEGE,
July 16th, 1879.

* p. 45. In the last line of the third paragraph, for $23AC'$ read $3AC'$.

A NEW METHOD OF CONSTRUCTING INDEX PLATES FOR GEAR CUTTERS.

By PROF. JOHN E. SWEET.

The making of practically perfect index plates for gear cutting machines is a different matter from graduating circles for astronomical instruments.

Imperfect as graduated circles prove to be, when subjected to the test of astronomical observations, or triangulating, as practiced by the Coast Survey, they are no doubt quite accurate enough for the index of a gear cutter; yet transferring the graduations from the circle to the index plate introduces sources of error, and besides, the graduations will serve for making but one of a hundred rows of holes, and thus, ninety-nine other rows would have to be produced by a repetition of the same tedious and even more difficult method—more difficult by the method of sub-division, at least, because 360 is divisible by bi-section to a low degree, while 97 or 89 are not.

An account of the different methods invented and tried for the division of the circle and the construction of index plates would be interesting; but one attempting to write such a history who had not made it a life study would be likely to omit more of the ways than he remembered to recount. So I describe the following method, which I believe to be new, leaving the history and comparison to the enthusiast or more experienced.

To make one or more plates with 69 circles of holes, increasing by 4 from 228 to 500, in a plate about 5 feet 6 inches in diameter, the following method is suggested:

500 hardened steel bushes, $\frac{4}{10}$ inch in diameter, about $\frac{1}{2}$ inch long, with holes perhaps $\frac{1}{10}$ inch in diameter through their centres, are to be used. The holes are to be ground perfectly true to size, on the system of the Whitworth cylindrical gauges, and their outer surfaces ground to perfect cylinders, uniform in size and concentric with the holes. Such work is now done by the "American Standard Gauge and Tool Company," and guaranteed to $\frac{1}{25000}$ inch.

The steel bushes, which serve the double purpose of dividing the circles and guiding the drill in drilling the plates, are to be used in the

following manner: A cast iron disc or template, $\frac{1}{2}$ inch thick, somewhat larger than the plate to be made, has on its lower side three projections, bored so as to embrace the outer edge of the plate, and locate the two, concentric with each other. The two being mounted in the lathe, a hole is bored in the template so as to embrace, by a close fit, 228 of the steel bushes when placed within its inner surface, the template to be warmed when the bushes are inserted, and allowed to shrink upon them.

Through these bushes the inner circle of holes is drilled, the bushes removed, and the template bored to contain 232 other bushes, through which the second circle of holes is drilled, and in like manner the other 67 circles.

By using the bushes successively, no bush would be used more than 51 times nor less than 50.

By this method the sources of error are reduced to a minimum. Just so perfect as the bushes can be ground, just about that perfect it might well be expected that the plate would be drilled. Probably drilling the holes $\frac{1}{12}$ or $\frac{1}{14}$ inch, and then enlarging them by a counter-bore to $\frac{1}{10}$ inch, would insure a more perfect result than by trusting to the drill for the finished hole.

Other precautions might be taken, such as drilling up, that is, with the face down; and some arrangement for heating the template with warm water before setting the bushes would be likely to insure more perfect results.

The cost of this method would be excessive, but if five or ten plates were made at the same time, the cost would be proportionately less.

Cornell University, Ithaca, N. Y.,
June 16th, 1879. }

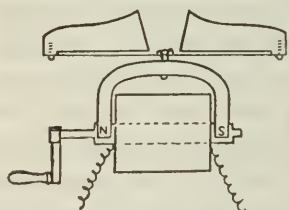
Glaciers in the Maritime Alps.—The existence of moraines on the Ligurian coast has often been questioned, and geologists have been unable to point to any conclusive evidence of a former icy sea, analogous to the one which had so many outlets in Piedmont. M. C. Desor after vainly exploring the neighborhood of Nice, has found well-marked moraines about 20 kilometres (12.43 miles) in the interior, at the foot of the jurassic masses which form the outposts of the mountains.—*Les Mondes*. C.

A NEW GENUS IN TELEPHONES.

By Prof. A. E. DOLBEAR.

The common form of speaking telephones relies for its action upon currents of electricity developed in helices by the varying strength of magnetic induction when an armature moves in the magnetic field. These currents, traversing other coils about the poles of a magnet, vary the inductive strength of it and thus set its armature in motion as the first is moved. There are many forms of these instruments, all known by the generic title of magneto-telephones.

Edison has developed out of his motograph, which was invented several years ago, a receiving telephone, which is said by those who have heard it to be surprisingly loud. Its principle of action is



entirely distinct from that of the magneto-telephone, and depends solely upon the varying friction between two surfaces, one of which is an electrolyte, when a varying current is passed between them. The stronger the current the less the friction, and these conditions are so rendered mechanically as to effect a transformation of electrical waves into corresponding sound waves in air. This is a distinct genus with but one species to represent it.

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The following is a description of still a third kind, as unlike either of the former as they are unlike each other. While experimenting with a common string telephone with a screw tied to the end of the short string of three or four inches, the screw being made the armature to an electro-magnet in circuit with an Edison transmitter, I found that the speech was rendered plainly when the screw adhered to the pole of the magnet, provided that the screw was slowly dragged over it while the variable current was passing. The interpretation of this phenomenon was instantly perceived and I have had constructed an instrument in which these conditions are employed to greater advantage. A short straight bar electro-magnet is furnished with a crank, as in the diagram, so it may be rotated within its coil. Lying upon the poles of this magnet are the ends of a bent armature, marked

N and *S*. The back of this armature is fastened to a plate of mica or paper, or thin iron, mounted as such plates are in ordinary receivers, so that any motion of the poles *N* and *S* will be imparted to the plate. Suppose a current of electricity traverses the bobbin, the straight bar becomes a magnet with strength proportionate to the strength of the current, and the armature will adhere to the poles of it with a certain degree of adhesion. Now let the crank be turned slowly, and the adhesion of the armature will result in stretching the plate and the cessation of the current will permit the plate to regain its former position through its own elasticity. A varying current will result in varying adhesions and the consequent vibrations of the plate, and talking may plainly be heard with an instrument constructed thus. This instrument I have named the *Rataphone*. Of course there are many ways in which this principle may be utilized. Instead of rotating the magnet the ends of the armature may be prolonged, and rest upon a cylinder or pulley, which may be rotated, and the varying attractions will cause the diaphragm to vibrate. If a strip of paper be put between the armature and the poles of a common relay or sounder, which is in circuit with a transmitter, and the paper be slowly drawn along while an intermittent or vibrating current passes, the ear applied to the paper will hear the sounds, and articulate speech, if the current be varied by such sounds, and if the armature itself be so made as to rotate, the same effects will be produced.

TUFT'S COLLEGE, *College Hill, Mass.*

Galvanic Dilatation.—In order to test Edwards' hypothesis that the passage of a galvanic current produces a mechanical elongation, M. Blondlot has contrived a delicate experiment. He takes a strip of copper, thoroughly annealed, which he bends into a kind of quadrangular spiral, fastened at its upper end and carrying at its lower extremity a shaft which plunges into mercury. When a current is passed through the spiral, all the angles should vary if there is any dilatation, and as all the variations are cumulative the terminal stalk should turn through an angle which could be easily measured by Poggendorff's method. An elongation of '00000025 could be readily detected in this way, but as he found none, Blondlot concludes that the hypothesis is incorrect.—*La Nature*. C.

RESEARCHES WITH PROF. HUGHES' AUDIOMETER.

Paper read before the Royal Society May 15, 1879,By BENJAMIN WARD RICHARDSON, M.D., LL.D., F.R.S.

Professor Hughes having done me the honor to show me first his newly invented instrument for the measurement of hearing, and having supplied me with an instrument for the purpose of testing the application of it for physiological and practical purposes, I have been enabled to make a considerable number of experiments, on which I venture to submit the following preliminary report:

The instrument, as it has been used, is before the Society. It consists of two Leclanché's cells for the battery, a new and simple microphonic key connected with the cells and with two fixed primary coils, and a secondary or induction coil, the terminals of which are attached to a telephone. The induction coil moves on a bar between the two fixed coils, and the bar is graduated into 200 parts, by which the readings of sound are taken. The graduated scale is divided into 20 centimetres, and each of these parts is subdivided into 10, so that the hearing may be tested from the maximum of 200 units to 0°—zero. The fixed coil on the right hand contains 6 metres of wire; the fixed coil on the left hand contains 100 metres. By this means a long scale from the left hand coil is produced. The secondary coil contains 100 metres of wire.

In using the instrument, one Leclanché's cell has been found sufficient, as a general rule, but two have been used in instances where the hearing of the person under test has been very defective. The Leclanché cell was selected by Professor Hughes as affording a reliable current for the purposes he had in view, and for standard comparisons. In using the instrument, the induction coil is moved along the scale from or towards the larger primary, as may be required, and the degrees or units of sound are read from the figures on the scale, the sound being made by the movement of the microphonic key between the battery and the primary coils.

The person whose hearing is being tested should sit in an easy position, and should not see the act of the observer in moving the microphonic key. For good observation, the room in which the experiment

is made should be large, and all external causes of sound, such as the ticking of clocks, the vibrations of windows and doors, the moving of feet and the singing from gas jets, should be silenced. The sifter should close the ear that is not applied to the telephone while he is listening for minute sounds, and should give his full and calm attention to the proceeding. Any excitement is likely to lead to error when refined measurements are required.

The instrument may be considered to afford the most satisfactory means for testing the hearing power of all persons who can define a sound. The range of sound is sufficient at the maximum— 200° —for everyone who is not absolutely deaf, 0° , or zero, is a point of positive silence from the instrument, or rather from the sound which it produces through the telephone.

One of the first facts learned with the audiometer is the suddenness with which the sound is lost to those who are listening. The sound is abruptly lost within a range of 2° ; that is within one-hundredth part of the entire scale. This is the case with those who are very deaf, as well as with those who hear readily, a fact originally noticed by Mr. Hughes, and which I have corroborated by fifty special observations on different persons presenting powers of hearing which varied from 200° to 140° as the extreme limit or capacity, to complete hearing through the whole scale down to zero. In these persons, when the observation was taken, under the strictest possible conditions for surrounding silence, the point between distinctness of sound and complete loss of it was not more than one-hundredth part of the scale.

In testing the capacity of hearing, it is noticeable that the power to detect the diminishing sound is maintained best by continuing the reduction in trace or line while the attention is fixed. A sudden break may cause the sound to be lost to the listener long before his real incapacity to hear is reached. If, for instance, the sound be very faintly heard at 15° , and the induction coil be suddenly moved to 5^{μ} , the sound at 5° may be quite inaudible; but if the coil be slowly moved, unit by unit, from 15° to 5° , the sound at 5° may be distinctly heard. Mr. Maitland Tate, C.E., who noticed this point very markedly in his own case, when I was submitting him to test, compared this to what is observed by the sense of sight in making surveys. The eye will follow a line to an extreme point with comparative readiness, but if it break away from it, the object seems to have disappeared.

The effect of filling the chest and holding the breath makes a differ-

ence in listeners. The capacity for hearing is for a few seconds increased by holding the breath. Mr. Tate, who could hear with his right ear only down to 8° under ordinary breathing, could hear down to 5° when he held his breath. Another gentleman, who could hear only down to 100° under ordinary breathing, could hear to 80° when the breath was held with the chest full. Holding the breath with the chest not full fails to produce the same result.

As a rule, the hearing of persons who are right handed is most refined in the right ear, and as most persons are right handed, it is found that the right ear is the best ear. This rule is, however, attended with many exceptions, since, for various reasons, some persons who use the right hand exclusively, practise for some particular purpose the use of the left ear, upon which that ear becomes more acute. Thus five physicians, who were right-handed but who had accustomed themselves to use the stethoscope with the left ear, could hear to zero on that side, but had lost from 4° to 5° on the right side. Four other persons who were similarly circumstanced were able at once to account for the fact by the habit they had acquired of listening to a public discourse or sermon from the left side. Another point of interest attaching to this observation is that the practice of using one ear for special refinement of the sense seems for the time slightly to impair the other ear, although there is no physical evidence of such impairment.

Connected with last-named fact is another, namely, that by this instrument the deaf are found to fail in capacity of hearing not only by reason of physical defect, but also by failure of memory of sounds. Thus in a youth who had suffered serious defect of hearing for seven years, owing to partial destruction of the tympanum, and who in the right ear could only detect sound at 107° , there was an inability to catch all the sound lying between 130° and 107° until he could remember what he had to listen for. By practising him then to detect the lowest sound that he was physically capable of receiving, I got him to detect this one sound more readily than those which came higher up. By further practice all the intervening sounds became audible with equal facility. These facts which have been confirmed by another observation on a different person, seem to me to indicate that deafness from imperfection of the tympanum or other parts of the organ of hearing may be increased, beyond the mere physical failure, either from some lost power of automatic adjustment in the auditory apparatus, or from failure of receptive power in the cerebrum itself, so that

the memory rendered imperfect is slow to assist the listener until by exercise of function its readiness is restored.

By the use of audiometer, the influence of atmospheric pressure on hearing is detectable. In my own case when the barometer is at 30° , I can hear on both sides close down to zero, but below 30° I fail by 2° on the left side to reach zero. In another person a similar failure extends to a loss of 4° .

I have tried to determine in some of the lower animals whether there is the same sense of hearing as in man. In most animals it is difficult to obtain sufficient quietude to enable the observer to gather from expression or movement of the animal the information sought for. In two dogs, one a terrier, the other a field spaniel, I succeeded in making some good observations, and in them the range of hearing power seemed to be distinctly lower than it is in the human subject who has perfect hearing. In both these animals, which were healthy and in the prime of life, the first indication of the detection of sound commenced at 10° on the scale. The detection was evidenced by the sudden expression of listening, by a slight change of position, and a slight dilatation of the pupils. This detection was clearly made on the instant, as if the sharp line of hearing were the same in them as it is in the higher animal.

PRACTICAL MEMORANDA.

1. The audiometer will, I think, be an essential in all physical examinations of men who are undergoing examination as to their fitness for special services requiring perfect hearing, such as soldiers, sentries, railway officials, and the like.

2. The instrument will be of great use to the physician in determining the value of hearing in those who are deaf, and in determining the relative value of the two organs of hearing. In one instance, already, I have been able by its means to detect in a person who was supposed to be equally deaf on both sides, that on one side the hearing is perfect close up to zero, while on the other side nine-tenths of the hearing is lost.

3. In other forms of diagnosis I have found the instrument useful. In a young person suffering from acute anemia the hearing was so defective that on the right side it failed to detect sound at 18° , and on the left side at 15° . In ten days, during which, under a new regimen, great improvement took place in strength and general condition, the

power of hearing had so much improved that the right ear was good down to 12° , and on the left to 3° ; an improvement of 6° on the right and of 12° on the left side.

In another person who was subject to repeated vertigo, the giddiness occurring three or four times a day, the hearing was so defective that although the external ear on each side was clear and the tympanum natural, no sound could be heard below 30° . Under complete rest and attention to diet, the vertiginous attacks were in a few days removed altogether, and with that removal there was gain of hearing, on both sides equally, up to 5° on the audiometric scale.

4. The instrument may be used to differentiate between deafness through the external ear and deafness from closure of the Eustachian tube,—throat deafness. In my own case I fail to detect sound by the mouth at 170° , and this I find is a fair average in those who are healthy. It represents the comparative value of communication by sound through the Eustachian canal and the external ear.

5. The instrument promises to be very useful in detecting the effects in the body of those agents which quicken or excite the circulation, such as alcohol and other similar chemical substances. I have some observations on these points in reserve for a further report.

6. The instrument promises to be of great service in determining the value of artificial tympanums in instances of deafness due to imperfection or destruction of the natural tympanum. The cotton artificial tympanums, introduced originally by the late Dr. Yearsley, and the membranous tympanums, introduced by the late Mr. Toynbee, F.R.S., have proved of much service; and by means of the audiometer I have been able very accurately to test their respective merits and to compare both with tympanums made of other material. The inquiry has led me to test different metals for this purpose, and to find in fine gold the substance for making the most useful and effective artificial drum. The Messrs. Ash, of Broad street, have made for me various forms of gold drums, the best of which, perhaps, is a little cylinder which, with other forms, is placed before the Society. With one of these cylinders I was able to give to a young gentleman who had lost hearing on the right side up to 110° , from destruction of the tympanum, an instant gain down to 60° , a gain of 50° on the audiometric scale.

In this preliminary report I have omitted many subjects of interest, but I hope I have related enough to show that the world of science in

general, and the world of medicine in particular, is under a deep debt of gratitude to Professor Hughes for his simple and beautiful instrument, which I have christened the audimeter, or less correctly but more euphoniously, the audiometer.—*The Telegraphic Journal*.

DEPREZ'S ELECTRO-MAGNETIC ENGINE.

By the COUNT DU MONCEL.

According to Count du Moncel, writing in *La Lumière Electrique*, M. Marcel Deprez has succeeded in solving the problem of making an electro-magnetic motor capable of doing useful work in many industrial applications. We venture to doubt whether the new motor can compete with even a water-motor as regards economy, to say nothing of gas and steam engines; but, according to Du Moncel, Deprez's apparatus is barely eight inches long, by less than six inches in breadth; it weighs about $6\frac{1}{2}$ pounds and can supply a power of nearly eight foot-pounds per second with five Bunsen elements. This, says Du Moncel, is really an extraordinary result, and one which could scarcely have been anticipated a few years ago. Under these conditions sewing machines may with perfect ease be worked by electricity without any cumbrous apparatus. This ingenious system consists of a horseshoe magnet of eight plates $5\frac{3}{4}$ inches in length, between the poles of which is introduced a Siemens armature, acted upon by the magnet over a length of $2\frac{3}{4}$ inches. Up to the present time no one has ever thought of causing magnets or electro-magnets to act otherwise than by their polar extremities, and all the engines devised hitherto have been arranged on this principle; but M. Marcel Deprez, thinking that under these conditions the whole of the magnetism that can produce a magnet was not utilized, endeavored to cause the whole of the sufficiently-magnetized portions of the magnet engine to act upon the mobile system to be influenced; that is to say, in the present case, the branches of the magnet nearly up to the neutral line. The electro-magnetic armature, instead of being placed transversely to the magnet, is arranged longitudinally and parallel to it. Under these conditions the magnetic power exerted on the armature is found to be considerably augmented, as is perceptible from the difficulty experienced in producing rotation, and this increase of force may give an idea of the consid-

erable advantages presented by this system of motor, which works by the effect of successive reversals of the current. Everybody knows the Siemens armature; it is a kind of galvanometer frame, of which two sides constitute the two poles of a straight electro-magnet with a flat core, broader than it is long, upon which the wire is wound. The axis of this electro-magnet is parallel to the coils of wire in the magnetizing helix, and consequently to the arms of the magnet. At one end it carries a reversing commutator, and at the other end it is provided with a pinion which gears into a wheel of which the diameter is thirty times greater. When the apparatus is properly regulated, the armature makes ninety revolutions per second, and, consequently, the wheel which it acts upon makes three revolutions. It is upon the axis of this wheel that are fixed the pulleys transmitting the movement, and by which the engine is caused to work either a sewing machine or any other apparatus which is to be set in movement. In order to render the working of the apparatus perfectly uniform, M. Marcel Deprez has adapted to it an extremely ingenious regulator, the action of which is very efficacious. It is a sort of spring fixed by one of its extremities to one of the ends of the armature. By means of a screw, a tension suitable for any given velocity of the engine is given to the spring. The transmission of the current from the commutator to the wire of the armature is effected without difficulty by this spring, as in the case of all frictional contacts; but when the velocity is greater than that which is requisite, centrifugal force is brought into action, and the mass of the spring causes it to fly off and to break the circuit, whence results a slackening of the speed, and then the completion of the circuit, which is again broken when the velocity again becomes too great. These alternations are so rapid when the electric power is somewhat higher than is strictly necessary, that a continuous spark is seen at the commutator where the regulating spring is in contact with it. Nothing can be simpler than this little apparatus, which, as at present constructed, may be of great service. Its force may be estimated by trying to stop the pulley, the diameter of which is nearly four inches. With five Bunsen elements at work, this stoppage can be effected only with great difficulty; whereas with the ordinary electro-magnetic engines it is easy to produce a stoppage by pressing a little upon the axis of rotation. Count du Moncel does not say what is the cost of five Bunsen elements, nor where they are to be placed when employed in working a sewing machine in a lady's boudoir.—*English Mechanic.*

REVERSAL OF MOTION WITHOUT GEARS OR BELTS.

Editor Journal Franklin Institute:

DEAR SIR—I note on page 417 of your issue for June, as a translation from a French journal, a description of an alleged invention of M. Bourdon for “reversing motion without gears or belts.” Just how old the method described may be I am not aware; but the first published account of it, within my knowledge, is contained in an illustrated work published at Lyons in 1719, which purports to be a description of the models contained in the cabinet of M. Grolier de Serviere, by his grandson; this would probably place the date of the invention (if original with M. G. Serviere) somewhere about 1650. In the work named it is shown as communicating motion from a horizontal crank shaft to a crank on the axis of a submerged rotary pump. Further, the device claimed as M. Bourdon’s invention was used in the second pumping engine erected (in 1857, I think) for the supply of water to the City of Chicago. In this particular case the motion was transmitted from an *eccentric* on the main shaft to a crank on the end of a revolving shaft, on which were the cams for actuating the valves of the engine. The same arrangement was repeated, with slight modification, in a pair of pumping engines built for the same city about ten years subsequently. I think the above-named engines were constructed at the Allaire works, New York.

Verily, such claims as those of M. Bourdon recall the saying of Chaucer: “Oute of olde bookes come all this new knowledge that men here.”

Yours truly,

W. F. DUFFEE, C. E.

Bridgeport, Conn.

Photographic Transit Measurements.—M. Cornu has been investigating the best theoretical conditions for measuring the photographs of the transit of Venus, with especial reference to the micrometric determination of angular distances. From Mouchez’s photographs he deduces a value, for the sum of the radii of the sun and Venus, which differs from the value in the *Connaissance des Temps* by less than $\frac{1}{4}$ of 1 per cent. This indicates a possibility of determining the sun’s distance, by photographic observations, within $\frac{1}{10}$ of 1 per cent., or within less than 100,000 miles.—*Comptes Rendus*. C.

GJERS' IMPROVEMENTS IN MAKING IRON AND STEEL.

Among the processes recently patented in connection with the dephosphorization of iron, that of Mr. Gjers, of Middlesbrough, is sure to attract attention. In the Bessemer process, as at present carried on for the manufacture of steel and ingot iron, the slag which is all formed in the early part of the blow from the oxidation of the silicon and some of the other impurities in the original pig iron is allowed to remain in the converter until the end of the process, and is continually being agitated and mixed up with the purified product. Experience has, according to Mr. Gjers, shown that it is not usually practicable to stop the process, as theoretically should be done, at the point when the desired percentage of carbon still remains in the steel; and the reason is chiefly that the tenacious silicious slag does not separate readily from the steel, but more or less contaminates it, and that when the charge works extra hot some of the silicious slag formed at first is even decomposed by the subsequent carbon flame, and causes some silicon to remain to the end, rendering such steel, if it is attempted to tap off before all the carbon is expelled, unworkable and of bad quality. The consequence is that more or less overblowing is resorted to, which again involves the use of spiegel or ferromanganese for the threefold purpose of deoxidizing the charge, rendering the slag more fluid so as to thoroughly separate it, and restoring the desired quantity of carbon. According to the invention patented by Mr. Gjers, as soon as all the slag has formed, and before or about the time when the carbon flame distinctly appears, the converter is turned down and the whole of the slag removed. The converter is then turned up and the blow continued as usual until the carbon is exhausted. Spiegel may then be added, but the patentee prefers, and is enabled through the absence of contaminating slag, to finish the process before the whole of the carbon is exhausted, and thus is able to produce a good and workable quality without the addition of spiegel. But where it is desirable to have a small quantity of manganese in the steel, he adds the desired quantity in the shape of rich ferromanganese in the solid state. In treating pig iron containing phosphorus he prefers to use a neutral or basic lining chiefly constituted of alumina or lime, which linings are now well known. He then charges with the fluid iron in the converter from 10

to 20 per cent., according to the amount of phosphorus and silicon the pig iron contains, of basic material, a mixture, say of 50 per cent. lime and 30 per cent. of rich oxide of iron (by preference magnetic), and 20 per cent. oxide of manganese, or other proportion of this or other basic material calculated to form a fusible slag with the silica formed by the oxidation of the silicon in the pig iron, and blow as above explained. The whole or the greater part of the phosphorus will be found to have left the iron and gone into the slag. In lieu of removing the slag from the converter by simply turning down and raking it off, it may in practice be found convenient to pour the metal out of the converter into a ladle, keeping the slag back, and then to empty the slag out of the converter and return the clean metal to the converter; or the partially blown metal and the slag may be poured into a ladle having a bottom plug, and the metal returned to the converter through the bottom hole, leaving the slag in the ladle. Mr. Gjers does not claim the use of a basic lining, or the adding of basic material to the charge in the converter, either separately or conjointly, but he claims as his invention removing the slag in the Bessemer process before or about the appearance of the carbon flame, and subsequently completing the blow.—*English Mechanic*.

BEET ROOT SUGAR.

The successful manufacture of beet sugar in Europe is one of the most surprising industrial achievements of the nineteenth century. It may be said to have grown up within the memory of men now living. For although in 1795 the Prussian chemist Aehard presented several loaves of refined beet sugar to the King of Prussia, the enterprise was at once discouraged and abandoned. It was renewed, in France, in 1810. In 1814 it began to flourish, and in 1825 France produced 5000 tons of beet sugar. In 1837 the production had grown to 49,000 tons. By that time it began to attract attention in the United States. In that year Mr. Samuel Blackwell, a sugar refiner of Bristol, England, who had moved to New York in 1832, and, in connection with English capitalists, had put up in 1835 the first steam sugar refinery with vacuum pans ever erected in America, made some excellent loaf sugar from beets raised by him in his garden at Jersey City from imported seed.

Convinced by this experiment that beet sugar could be profitably

made by free labor in the United States, in competition with the West Indies and Louisiana, Mr. Blackwell moved to Ohio in 1838 for the purpose of engaging in its manufacture, but died a few weeks afterwards. Mr. David Lee Child, a little later, attempted its production in Northampton, Mass., and reported favorably, but failed to make it profitable. In 1861 Mr. E. T. Gamert attempted it on a larger scale in Chatsworth, Ill., but was unsuccessful. Small factories have worked with moderate success in Freeport, Ill., and in Fond du Lac, Wis., but have ceased to exist.

In California several factories have attained a certain measure of success. But these experiments have all been made with insufficient capital, and on a scale too small for profit. The great difficulty has been the want of sufficient beets at reasonable prices, their cultivation being almost unknown to American farmers. But during the last half century Europe has steadily developed the beet sugar industry. From 5000 tons of sugar in 1825, the annual product has become 1,500,000 tons, worth, at our present low scale of prices, about two hundred million dollars a year. More than one-third of all the sugar used in the world is now made from beets. Indeed, the progress of the industry is such throughout Continental Europe that it is predicted cane sugar will at no distant date cease to be used there.

In view of these facts, and of the vast sums annually paid by the United States for sugar and molasses—amounting to about one hundred million dollars per annum—the question arises, Why should not America make her own sugar from beets? Everybody knows that the beet grows luxuriantly in our soil and climate. The root contains as much sugar here as there. Against the cheap labor of Europe we have the advantages of cheaper land and cheaper fuel. Our farmers sell yearly to Europe other agricultural products—wheat, corn, cotton, cattle, cheese, etc., amounting to millions of dollars. Our sugar refiners are unequaled in skill and ability. Sugar is refined to-day more cheaply in America than in Europe. Why, then, do we not make our sugar? The answer is simply this: Everything must have a beginning. This is a new industry, unknown to the farmers who settled America. There is a great practical difficulty in changing an established system. Sugar is produced so cheaply by slave labor, and is imported on so large a scale, that it can only be profitably made on a great scale and with costly machinery. No capitalist will invest one hundred and fifty

thousand dollars in machinery to work beets that do not exist. No farmers will raise beets until a sugar factory is ready to buy them.

This almost impassable gap between the capitalist who cannot raise the beets and the farmer who cannot make the sugar, has at last been bridged by the Maine Beet Sugar Company, which last year made 183,000 pounds of beet sugar, is now erecting the best European machinery, and has contracted with 1700 farmers for 1250 acres of sugar beets. Under the stimulus of a State bounty of one cent per pound on the sugar produced, this company has leased the Forest City Sugar Refinery in Portland, Me., for the fall and winter months, and has expended a large sum in additional machinery. Next fall there is reason to believe that the experiment of making beet sugar in America will be fully and fairly tried in Maine. Indeed, the question will be reduced to this: "Can beets be raised by American farmers in quantities and at prices which will justify their conversion into beet sugar?" The result of the experiment will be awaited with general interest.—*Boston Advertiser.*

ON THE USE OF DETERMINING SLAG DENSITIES IN SMELTING.

By THOMAS MACFARLANE.

A paper read at the Pittsburgh Meeting of the American Institute of Mining Engineers, May, 1879.

In smelting copper, lead and silver ores, it is scarcely possible in every case to make analyses of the various parcels of ore, with the view of combining these and the fluxes, so accurately as to yield, in the furnace, slags of exactly the most favorable composition. This is even more difficult with ores which require previous calcination, or with mattes which have been roasted in heaps. Even in cases where the greatest pains have been taken and the most elaborate calculations made beforehand, it frequently happens that variations in the working of the furnace interfere with the result so much desired. Generally, the practical metallurgist must be content with ascertaining the average composition of his ores and fluxes, making a calculation once for all as to the most advantageous mixture, and leaving slight changes in its composition to be taken care of as it is passing through the furnace.

The various products then afford him the best material whereon to base his judgment as to the manner in which his smelting mixture and the furnace are working. Of course the character of the slag is one of his chief guides, but it is not always possible from its outward characters alone to form a correct judgment as to its composition. Neither would it be possible or practicable to apply chemical analysis for this purpose, as it would be impossible to wait for its results while working a furnace.

Abich was, I believe, the first to point out the relation existing between the composition of volcanic rocks and their densities, and to show that the latter being ascertained, very correct conclusions might be drawn as to their content of silica. The general rule is that the most siliceous rocks are the lightest, and the most basic have the highest specific gravity. It occurred to me that by determining the density of slags it might be possible to judge more accurately of their nature than by observing merely their superficial appearance. This plan was first applied at the Wyandotte Silver Smelting and Refining Works in September, 1877, when siliceous silver ores and galenas from Georgetown, Colorado, were being treated. Mr. F. H. Williams determined the following densities and silica contents of the slags from these ores :

Density.					Per cent. SiO_2 .
3.44	.	.	.	.	37.6
3.48	.	.	.	.	36.35
3.50	.	.	.	.	36.3
3.51	.	.	.	.	35.8
3.56	.	.	.	.	35.15
3.57	.	.	.	.	33.90
3.63	.	.	.	.	31.15
3.88	.	.	.	.	30.40

In July and August, 1878, Mr. S. B. Wight made the following examinations of three slags from one and the same smelting campaign during which Western ores were being treated :

Sp. gr.	Per cent. SiO_2 .	Al_2O_3 .	FeO.	CaO.
3.47	. . 35.05	Undetermined.	31.51	. 15.77
3.52	. . 32.56	"	37.70	. 14.68
3.60	. . 31.96	"	36.97	. 12.71

The gradual increase of density as the silica decreases in both these

series of examinations will be apparent. But the rule is not absolute, and is only applicable where the relative quantity of the different bases in a slag remains the same. In smelting ferruginous ores and lead and copper mattes the quantity of protoxide of iron in the slag in proportion to the other bases is usually greater, and this increases the density, although the percentage of silica may remain the same. A slag from smelting lead matte gave, on examination by Mr. S. B. Wight, as follows:

Specific gravity,	.	.	.	3.65
Silica,	.	.	.	34.67
Alumina,	.	.	.	14.85
Ferrous oxide,	.	.	.	39.04
Lime,	.	.	.	7.54

If this example is compared with the first in the last-mentioned series it will be found that an increase of 7.53 per cent. in the ferrous oxide, while the silica remains nearly the same, causes a considerable increase in density. The following determinations are further generally illustrative of the increase of density in slags as their percentage of silica decreases:

Where produced.	Sp. gr.	SiO ₂ .	Al ₂ O ₃ .	FeO.	CaO.
Iron Blast Furnace, Wyandotte,	2.85	55	Undetermined.		
Copper Works, Detroit,	3.04	43.31	26.22	—	27.40
Germania Works, Utah,	3.81	28.01	Und.	48.10	12.37
Eureka Consolidated Works, Nevada,	4.13	26.47	"	61.62	2.73
Wyandotte Rolling Mills ("heating slag"),	4.29	25.49	"	75.06	—

Some of these determinations are by Dr. Hermann Hahn, others by Mr. S. B. Wight.

In practically making use of the slag densities for regulating the smelting at Wyandotte Silver Smelting and Refining Works, Jolly's spring balance (described at page 59 of Brush's *Determinative Mineralogy*) was found of great service. Five minutes only are used in making, by its use, two determinations of the density of a slag, and then it is found easy to decide whether any change in the smelting charge is necessary. The smelting of ore goes on regularly and cleanly when the specific gravity of the slag is kept between 3.6 and 3.8. Water-jacket furnaces are used, with six tuyeres, and a height from these to the charging-door of 12 feet. The crucible of each

furnace is 18 inches deep, and furnished with a tapping-hole at the bottom, besides the usual "lead-well" and slag-spout. The tapping occasions no difficulty, and so long as the slag is not allowed to become too heavy no incrustations are deposited in the furnace, which is easily cleaned out at the end of each campaign. The charging is managed in the following way: The smelting mixture is made up of ore and fluxes, and is calculated to yield a slag containing 32 per cent. silica. The slag necessary to keep the charge open is added separately in the proportion of about one-third of the smelting mixture. The slag used is unclean slag from previous campaigns and puddling slag or heating slag (*frischschlacke*) from the rolling mills. When the furnace yields a slag of greater density than 3.8 the proportion of rolling-mill slag is decreased. The latter is on the other hand increased when the slag produced is lighter than 3.6. By ascertaining the specific gravity of the slags frequently, and altering the charge in the manner described, the furnaces are found to work regularly and satisfactorily.

It is not supposed that the exact figures above given will be found of great value in other smelting works, or that by attending only to the composition of slags in smelting it will be possible to do the best of work. The metallurgist has very many points to consider at one and the same time while conducting smelting operations, and the object of this paper is merely to direct his attention to one of these points and to indicate a mode of ascertaining approximatively the amount of silica in slags with comparative ease and accuracy.

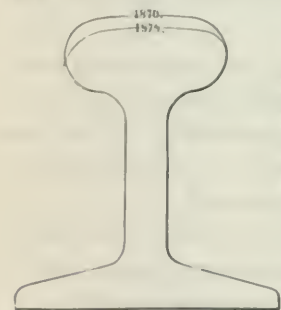
Transformations of Nervous Phenomena.—In reviewing the affections and the nervous phenomena which are propagated by a transmission and a transformation of motion, from simple yawning to epilepsy, fascination, panic, etc., J. Ramboisson formulates the following general principle: A purely physical movement may be transformed into a physiological and into a psychic or cerebral movement by simple transmission to special portions of the system, and reciprocally, a psychic movement can be transformed into a physiological and into a physical movement by simple transmission to a different portion of the system, and that without losing its character; for it reproduces the same phenomena, after all these transmissions and transformations.—*Comptes Rendus.* C.

NOTE ON THE WEAR OF AN IRON RAIL.

By W. E. C. COXE.

A paper read at the Pittsburgh meeting of the American Institute of Mining Engineers, May, 1879.

At a meeting of the Institute in Philadelphia, in June, 1876, it was my pleasure to read a paper on the "Manufacture and Endurance of Iron Rails." I then spoke of some trial rails which had been placed in the down track of the Philadelphia & Reading Railroad, over which passed, in addition to merchandise and passengers, most of the heavy coal traffic of that company. One of these rails, made at the Philadelphia & Reading Rolling Mill in 1870, and then placed in the track, was removed in 1876, after having carried about 55,000,000 gross



tons, and was on exhibition at the Centennial Exhibition. A piece of this worn rail, twisted cold, was also shown there. One of the same series of rails was allowed to remain in the track until 1878, and short sections of this rail, as well as one not worn, to show its original shape, are presented for your inspection. A comparison of the two will show that the top of the head or tread has worn down $\frac{3}{16}$ ths of an inch during its nine years of service. It

carried in that time 67,000,000 gross tons of freight, passengers, cars and engines. This rail was made in the usual way of manufacturing iron rails at the Philadelphia & Reading Rolling Mill. The head was made from puddled iron bars, piled, heated and rolled into bars $4\frac{1}{2}$ and 3 inches wide by 1 inch thick, these bars breaking joints, heated and rolled into slabs 9 inches wide and 2 inches thick; the balance of the rail pile, which is in section 9 inches square, was made of $4\frac{1}{2}$ and 3 inch bars, rolled from two-thirds old rails and one-third puddled iron. This was heated and bloomed, and then reheated before rolling in two-high rolls into the finished rail.

The test-pieces from the head bar of this rail gave a tensile strength of 63,000 pounds. The borings from the head of the worn-out rail analyzed as follows:

Phosphorus, ...	·422
Carbon, ...	·027
Silica, ...	·392
Sulphur, ...	·032
Manganese, ...	·164
Iron, ...	98·963
	100·000

In making comparisons of the endurance or wearing qualities of iron and steel rails only the best of each kind should be taken, and the difference will not be nearly as great as has generally been assumed.

BOILER EXPLOSION.

A very disastrous explosion of a steam boiler occurred on the morning of June 27th, 1879, attended with the loss of life of the engineer and of a woman and two children, occupants of a house near the boiler house. The scene of the disaster was the planing mill of A. Wilts & Son, Nos. 721 to 727 North Front street in this city, where the boiler was in use for furnishing steam for the motive power (perhaps some 120 horse-power actual) of the planing mill.

The boiler itself was what is known to boiler makers in this vicinity as "a double-decked boiler," consisting of a lower horizontal cylinder, four feet six inches in diameter by twelve feet long, having 71 tubes, three and a half inches in diameter, spaced about one inch apart, thus filling this cylinder, except about four inches of water space and a man-hole space below the tubes completely. This lower cylinder was connected by four necks each one foot in diameter by about one foot long to an upper cylinder three feet six inches in diameter by fifteen feet long, over dished ends, and this again was joined by two necks, each one foot in diameter by about one foot long, to another cylinder or steam drum two feet in diameter by eight feet long over all.

The lower water line was supposed to be midway on the second of these cylinders, with gauge cocks (two above low water) about three inches apart. The boiler was made ten years since by Hunsworth & Naylor, of this city, from the best charcoal-hammered iron, and had been overhauled, furnished with new tubes and otherwise restored to the condition of what was thought equal to a new boiler six months since.

The joints were all single riveted. It had besides been examined with great care and tested by the officials of the Hartford Boiler Insurance Company, whose certificate or acceptance is equivalent to the city inspection according to law.

The destruction of the shell of the lower cylinder was very complete. One portion of horizontal joints about three feet in length (where a new sheet joined the old) only parted on the line of the joint, along the rivet holes of the old plate, while the waist of this shell was torn out diagonally across solid iron and on the lines of vertical seams, and the flattened plate of metal was hurled perhaps two hundred feet. The two heads were forcibly dished two or three inches by the resistance which the tubes offered to the explosion, one retaining all the tubes being driven against the brick work of the stack and setting at the back end, and the other was impelled across the street and lodged in the second story of a brick dwelling opposite. The remains of the engineer were found under this head. The upper portion of the boiler complete was torn off from the lower by the rupture of the four necks and thrown sidewise upon and demolished a frame dwelling near by. The woman and children killed were in this house.

Examination of the boiler after the explosion showed no deterioration apparent in the way of corrosion, and computation of strength gave adequate dimension for 80 pounds pressure of steam per square inch.

Test of the iron gave fair strength of material with perhaps some want of ductility not uncommon in charcoal bloom hammered iron made previous to the lawful tests for ductility as well as strength. The proportion and operation of the two safety valves were all that could be wished. The competency and carefulness of the engineer was maintained by all witnesses. No blame could be attached to any one with any fairness for the occurrence of this disaster.

This kind of steam boiler is peculiar to Philadelphia and its vicinity. Perhaps some 600 in all of them exist hereabout in use to-day, but they have met with no favor elsewhere. They are very economical as steam makers; they supply dry steam, they are easy to clean, to examine and to repair. The water line is very steady and well marked. But this is number five of them which within fourteen or fifteen years have exploded disastrously. The natural end of all boilers is to wear out; they show signs of decay, become leaky, are repaired, patched, caulked, finally after manifest imperfection they will be con-

demned and broken up. For one boiler that explodes destructively many hundred peaceably go out of existence.

The coroner's jury found "That the bursting of the boiler was the result of the use of an inferior quality of iron in the shell of the tubular boiler, conjointly with improper repairing and injudicious application of the hydraulic test."

STEAM ENGINES AT THE ROYAL AGRICULTURAL SOCIETY'S SHOW.

In the practice of Messrs. Marshall, Sons & Co., of Gainsborough, will be found much which will repay a visit to their stand. They exhibit no fewer than fourteen engines, of which two are vertical engines, two are traction engines, and two are horizontal stationary engines. The most attractive exhibit for engineers is one of the traction engines of eight horse-power. This engine embodies much that is new, and it is specially remarkable for the adoption of a singular device in connection with the valve gear, which illustrates very forcibly the difficulties which attend the reduction of theory to practice. It will probably be conceded without question that the more sensitive a governor is, the more uniform will be the speed of an engine. We suppose that to this there can hardly be a dissenting voice, yet in practice it is found that nothing can be much further from the truth. The traction engine in question has a single cylinder, $9\frac{1}{4}$ inch diameter by 12 inch stroke, and it is nominally of eight horse-power, and capable of working up to about forty horse-power, with 120 pounds of steam. The engine is intended for general use, and to drive a threshing machine among other duties. It is clear that if the ordinary reversing gear link motion could be combined with a governor much would be gained, the ratio of expansion being then determined automatically to suit the load on the engine. Hitherto all attempts to put this system in practice have failed, because the resistance of the ordinary slide valve is so great that no governor could properly control the link. Messrs. Marshall have got over this difficulty by substituting one of Church's patent balanced circular slide valves for the ordinary valve. Church's valves modified have been used by Mr. Webb, of Crewe, in locomotive practice, for some time, and Messrs. John Fowler & Co. applied them last year to ploughing engines. The resistance of the valve is so small

that it has been found possible by Messrs. Marshall to combine one of Hartnell's governors with the link. Hartnell's is one of the most sensitive governors in existence, and the result of the first experiments made with the combination to which we refer were far from satisfactory. It was impossible to keep the governor from hunting, with the result that although the engine made the same number of revolutions per minute, its rate continually altered during that minute. Thus ten or a dozen revolutions might be made at the rate of 150 a minute, while the ten revolutions preceding might be at the rate of 160, and the ten following at 140. The difficulty was finally overcome by putting a brake on the governor, which to a large extent renders it less sensitive, and it becomes an open question whether an ordinary slow speed governor would not answer far better. We may, while on this subject, add that Messrs. R. Garrett & Sons have found just the same difficulty with the cosine governor applied to an ordinary throttle valve, numerous adjustments having to be made to keep it from hunting. The bearing of this point on the electric light is of much interest. It is well known that equable driving of the Gramme or other electro-dynamic machine is of the utmost importance, to prevent flickering. At the same time it is a matter of comparatively small importance whether the machine is run at 700, or 750, or even 800 revolutions per minute. Heretofore engineers have always attempted to get perfectly uniform driving by using very sensitive governors, but there is reason to believe that these are precisely the governors which permit the greatest number of variations in speed. Let it be borne in mind that an increase or diminution in the speed of an engine producing the electric light of even a few feet of piston speed per minute in any one revolution produces a flicker, and it will be seen that a governor which may be perfect in the sense that half the load may be thrown off or put on without materially affecting the average velocity of the engine measured by the whole number of revolutions per minute, may be very defective in the sense that it permits the engine to make wide excursions above and below the average velocity, although such excursions last but a short time. Messrs. Garrett inform us that they have sold a considerable number of engines for driving electro-dynamic machines abroad, all of which are fitted with common governors. They have never heard of any flickering in the light produced by such engines, but they cannot say so much of engines fitted with sensitive governors.

The matter is one well worth the consideration of electricians and engineers alike.

Returning to the consideration of Messrs. Marshall's practice, we may add to what we have already written concerning it, that in all their engines they now adopt the system of lining the cylinder. It is cast of the best cold blast iron, and then bored out, suitable internal projecting rings being left at each end. A second cylinder, cast of a very hard mixture, is then turned accurately to gauge on the outside, and forced into the outer cylinder by hydraulic pressure. The space between the two forms a steam jacket. The pistons are packed each with two cast iron plain rings, cut through diagonally and sprung into the recess in the piston body. They are forced out against the cylinder by a single spring ring inside as wide as both the packing rings together. The piston rings are cast of a mixture of Blaenavon, Parkhead and Gartsherrie iron, melted in crucibles in the brass foundry and such rings are found to wear admirably. In such practice as this we have an example of skill, forethought and resource which is certainly not exceeded in any other branch of mechanical engineering. As to the results obtained with the combination of the Church valve and automatic governor we shall speak fully when we illustrate the engine to which it is fitted. It must suffice to say now that the indicator cards obtained are very good, being identical with those obtained from railway locomotives when worked at various grades of expansion.

Messrs. Davey, Paxman & Co. show an engine, among several others, in which automatic expansion is obtained in a very novel way. It may be remembered that at the Cardiff show, in 1872, this firm sent a portable engine for trial, which gave an excellent duty. It was the first racing engine ever made by the firm, and had not a crank shaft bearing been screwed down too tight, and heated in consequence, it would have made one of the best performances on the brake on record. Its mechanical time was 4 hours 18·17 minutes, and its consumption of fuel but 3·23 pounds of coal per horse per hour. The boiler evaporated 9·97 pounds of water per pound of coal, or about 1·33 pound less than that of the first-prize engine, or say 11 per cent. less. Had the boilers been equally efficient, Messrs. Davey, Paxman & Co.'s engine would have made over $4\frac{3}{4}$ hours mechanical time. This excellent performance was due, in large measure, to the use of a gridiron cut-off valve worked by a double cam on the crank shaft. The expansion curve obtained by this means was nearly perfect, indeed no better

diagrams were obtained. There were certain drawbacks to this method of driving a cut-off valve—although we may add that since 1872 the Cardiff engine has done a great deal of work, with much economy, the valve gear giving no trouble. In the engine exhibited, Mr. Paxman has retained the good features of the gridiron cut-off while getting rid of the cam. The engine is twelve horse-power, horizontal, of the girder type. The arrangements for setting up the crosshead bearings and those of the crank shaft are very ingenious and well worked out. The valve gear consists of an ordinary slide valve with full travel and very little lap or lead. It works as close as possible to a partition, in the same plane, in the valve box. In this partition are made three ports, and over them slides a gridiron valve, which is the cut-off valve, as no steam can get to the main, or distributing valve, without passing first through the ports in the partition before mentioned. The cut-off valve is driven in the following way: On a stud in the frame revolve two small eccentrics pinned to a toothed wheel, the rods of these eccentrics actuate a link uniting their ends, and this link drives the spindle of the cut-off valve. On the crank shaft is keyed a wheel just twice the diameter of that carrying the eccentrics, which last, accordingly, makes two revolutions for one of the engine. The eccentrics are called positive and negative, and are so set that while one tends always to keep the cut-off valve open the whole time a steam port is open, the other tends equally to keep the gridiron ports shut whenever a main steam port is uncovered by the slide valve. According to the position of the link, one or other will have most control over the cut-off valve. A high speed governor of the Porter type is connected direct to the end of the link, and shifts it to any required position. We have seen this engine under steam and its action was in every way satisfactory; the wheels being carefully cut, run practically without noise; the governor acts freely. There is no complication of parts, and altogether this may perhaps be regarded as one of the most satisfactory automatic expansion gears of the many which have been brought out of late years, while the engine, taken as a whole, is strong, neat and serviceable.—*The Engineer*.

China claims the Telephone.—The *Pekin Official Times* publishes a communication from a Chinese servant, asserting that the telephone was in use A. D. 922, and that it was invented by a citizen of Pekin.—*Fortschr. der Zeit*. C.

A NEW HARMONOGRAPH: INDUCTION BALANCE.

Mr. W. J. Wilson exhibited before the Physical Society, May 24th, a new harmonograph and figures drawn by it. The figures drawn by prior harmonographs are all more or less imperfect owing to loss of motion in the pendulums actuating the marking pen; and Mr. Wilson therefore designed a new harmonograph which not only gives perfect figures but admits of the phase of either of the two compounded motions being decreased by a known amount. In this instrument toothed wheels take the place of pendulums, the ratio of the teeth giving the ratio of the periods of the motions. By employing the device of an intermediate wheel gearing with two others, and arranging two or more wheels on the intermediate axle, a great variety of phase can be obtained for each motion. An ingenious adjustment by means of a movable nut allows the phase of either or both motions to be altered to a known extent, and thus an endless variety of figures can be obtained. As in other harmonographs a writing-table on which the paper is placed, and an aniline glass pen, are used. Several of the figures done also on glass were thrown on the screen, the stereoscopic effect being very apparent. In reply to a query Mr. Wilson said that he had adapted some of the figures to the stereoscope. Prof. Hughes explained his new induction balance and showed some of its principal effects. It is well known that on starting an electric current along a wire adjacent to another wire, an induced current is set up in the second wire in an opposite direction to the first or primary current. In the induction balance two primary circuits or coils are taken, with the same current (interrupted by a microphone acted upon by the ticking of a clock) running through both; and between these is placed a secondary circuit or coil in connection with a telephone. The primary coils are so wound as to oppose each other's induction on the intermediate secondary. There is a point, moreover, between these, where these opposed inductive influences exactly neutralize each other. If the secondary coil be placed there, no induced ticking of the clock can be heard; but if the secondary be displaced to one or other side of this point, the ticking can be heard in the telephone increasing in loudness as the secondary approaches one or other of the primaries. If the distance between the primaries be graduated into a scale, this contriv-

ance becomes a sonometer, since it gives an absolute zero of sound, and degrees of loudness. It is well adapted for measuring the hearing power of the ear. By splitting the secondary coil into two parts and placing each close to its proper primary, so that there are four coils in all arranged in two pairs, the extremes in one primary circuit, and the means in one secondary, the two opposing parts of the balance can be separated from each other, so as not to disturb each other's action, and the balance made very sensitive by the closeness of the primaries and secondaries. Prof. Hughes finds that there is a line or zone of maximum induction midway between each primary and its secondary. If a conductor, such as a piece of metal, be put in this position, it has a maximum disturbing effect on the balance, due probably to the electric currents generated in it by the induction. The effect is apparently proportional to the conductivity of the metal. It requires an exactly similar piece of metal put between the other pair of coils to restore the equilibrium of the balance. A difference of alloy, or of weight between two like coins is at once observed from the imperfect restitution of the balance; base coins are thus also at once detected. Again, it is possible for a person to tell what particular coin or coins are in one part of the balance by trial of the same coin in his part. When plates of non-magnetic metals are held vertical in the balance their disturbing effect is *nil*; iron on the other hand gives its maximum effect on this position, because its magnetic effect overbalances its electrical effect. Two pieces of iron may therefore neutralize each other as cores in an induction coil. Steel is easy to balance compared with soft iron. Zinc disturbs most when placed along the sides of each pair of coils; iron when in centre at a certain length of metal laid along the outsides of the coils produces silence. The maximum line of inductive force is midway between the coils, and there is a line of minimum force at half the thickness of each coil. A metal placed at these lines of minimum force has no disturbing effect on the balance. Pressure applied to small shot, or spongy gold, alters the balance. The effects of stress, heat, magnetism, light, etc., on matter could be determined by the balance. Prof. W. G. Adams believed that one result of Prof. Hughes' experiments will be the determination of the way in which the law of electro-dynamic induction depends on density. He also imagined that the metal when in the maximum line between the coils gathered the lines of force to itself, whereas when on the minimum lines it could not thus divert them. Prof. Ayrton cited the early

experiment of Faraday with a sheet of copper oscillating to rest between two opposite magnetic poles. The copper took a long time to stop; but a sheet of iron placed between two like poles was soon stopped owing to its becoming imbued with an opposite polarity, and deflecting the lines of force. He also suggested that the divergence of the results for conductivity of metals got by the induction balance from those got by the Wheatstone balance might be due to that electric inertia suspected by Sir William Thomson. Prof. Guthrie thought that the induction balance pointed to the conclusion that the disturbing effect of a conducting mass applied in this way is proportional to the quantity of electricity generated in it under certain conditions of temperature, etc. The determination of the conductivity of liquids, would be a useful application of the balance. Mr. Chandler Roberts gave some results which he had obtained from an examination of certain alloys by means of the induction balance. He had been able to detect a difference of one part in 1000 in the amount of silver in two shillings of equal weight. He also pointed out that Mathiessen divided alloys into three classes: (1) solidified solutions of one metal in another; (2) solidified solutions of one metal in an allotropic modification of another metal; (3) solidified solutions of allotropic modifications of both metals. For the first class the curve of electric conductivity is a straight line, for the second a parabolic curve, for the third a bent line. Mr. Roberts found that the balance gave the characteristic curve for the first class with an alloy of lead and tin, and for the second with an alloy of gold and silver. With a copper tin alloy, which is a good example of the third class, he found the curve given by the balance to be intermediate between Alfred Risch's curve of density and Mathiessen's curve of conductivity, and considers that the balance is influenced by the density as well as the conductivity of the metal interposed. Prof. Hughes said that as the working of metals appeared to affect their conductivity he was inclined to rely more on the conductivity measurements of the balance than on those of the Wheatstone bridge. By the balance plain pieces of metal were taken, whereas by the bridge wires were mostly taken. He would rather not give any theory yet as to the results obtained from the balance. Dr. Erek then exhibited his novel pump for lifting solutions out of batteries. It consists of a closed vessel, funnel-like, the stem dipping into mercury, a column of which ascends the latter to a certain height.

Two tubes emerge from the cover, one dipping into the liquid, the other opening to the air. By altering the pressure inside the vessel the solution rises to the latter, and can escape from it by trickling through the mercury.

AN ALARM COMPASS.

A very ingenious application of electricity to the purposes of navigation has recently been effected by Mr. Henry A. Severn, of Hernehill, who has succeeded in producing a mariner's compass which enables the captain or officer in charge to hear, by the ringing of a bell, when the vessel is out of the ordered course. In the construction of this compass Mr. Severn has availed himself of the constant position of the card and the ever-varying position of the ship for the purpose of making and breaking metallic contact, which causes an electric bell to be sounded, and thus to announce the fact that the vessel is off her course. The whole of the apparatus is contained in a small box, which is easily carried about, and is intended, as a rule, to be placed in the captain's cabin. Over the card are two index hands, which can be adjusted to any angle allowing of greater or less deviation in steering to either the port or starboard side.

Assuming the captain, on quitting the deck, to have given instructions to steer the ship on a certain course, he sets the index hands to a certain angle, allowing the steersman a given latitude for deviation either to port or starboard of that course. Instead of having to be constantly watching the compass, as at present, to see that his orders are carried out, the captain leaves the instrument to tell him by its silence if they are, and by its sounds if they are not, obeyed. Should the ship be steered off her course beyond the limit allowed on either side, an electric alarm bell rings instantaneously, and moreover continues ringing until the right course is resumed. The index hands can be raised away from the card, when the bell becomes disconnected and the compass can be used like an ordinary one.

The means whereby this useful result is attained may be thus briefly stated. The metal point upon which the card is hung is insulated from the compass bowl, and to it is attached a wire from one pole of a small battery. About an inch above the card, placed parallel to its surface and attached to its metal centre (which is insulated from the

needle), is an arm of metal reaching nearly to the edge of the card. This arm is therefore in metallic communication with the wire from the battery already referred to. The glass lid of the compass has a short brass rod working within a tube passing through it. These are severally attached to two brass milled heads above the glass lid, and to the two movable index hands beneath the glass. These are in metallic contact with the brass-work of the compass, and this with the other pole of the battery. Beneath the outer extremities of the index hands are suspended two pieces of platinum wire about three-quarters of an inch long. These hands can, by means of the two milled heads, be moved round to any position over any point of the card. Hence they admit of being placed on either side and equally distant or otherwise from the end of the metal arm on the card.

It will thus be seen that whenever the platinum wires come into contact with the metal arm on the card the circuit is completed. The electric bell being placed in the circuit sounds whenever such contact takes place. The bell is disconnected by simply raising the milled head up half an inch through a sliding tube, and the compass then becomes in all respects an ordinary one. Two bells of different tone can be used, and thus the instrument will indicate to the captain whether the deviation in steering is to port or starboard. The arrangement is simple and compact, and the invention promises to subserve a very useful purpose in navigation. By its use the captain will be saved much anxiety, and the knowledge that there is a check upon them will serve to render officers more vigilant and steersmen more careful. Headlands and rocks may thus be guarded against with much greater security, while in the case of vessels riding at anchor in a port or road, this compass will at once give intimation of swinging—a matter of importance, especially at night, when many vessels are together. In short, the dangers of navigation generally will be considerably lessened by its use.

Economy of Electric Carbons.—M. Delaurier says that by guarding the poles of the electric circuit from air currents, an atmosphere of carbonic acid may be formed around them, which prevents useless waste and greatly diminishes the cost of lighting by electricity.—*Les Mondes*. C.

AUTOTYPES.

For about ten years a process of photographic printing yecept "autotype" has been growing into notice, and asserting its right to occupy the field of art photography. It not only claims to have solved the problem of rendering the photographic image inalterable, but by the command of a wide range of monochromic effect, and of different surfaces for the reception of the picture, to have rendered practicable the reproduction of an artist's work in fac-simile. For example, an artist expresses his ideas in charcoal, in crayon, in sepia, or red chalk; the process is able to replicate his work, the same size, or larger, or smaller, employing the pigment of the original and the same kind of paper or foundation. The copy in such case may reasonably be believed to be as permanent as the original. A drawing or other artistic work reproduced by ordinary photographic means is palpably but a photograph: printed in autotype it will be so close a fac-simile of the original as not easily to be distinguished from it.

The autotype thus claims under favorable circumstances to reproduce the very body and soul of an artist's work—his touch and sentiment, with the actual pigment of his palette and the material he works upon. Effecting this by chemical means without the intervention of another hand, the process found a sponsor to name it autotype.

The starting point of all photographic pictures is the production of a negative in the camera. The negative becomes a matrix of endless prints. Most of our readers are familiar with a negative, and have noticed how the lights and shadows of the image on the glass are reversed; the high lights of the subject being represented by a dense deposit, while its shadows approach the condition of clear glass. It follows that light will be retarded in its passage through a negative exactly in proportion to the varying density of the image on its surface, and the art of photographic printing consists in providing that the transmitted light shall impinge on a surface sensitive to its impression. This has hitherto been effected by the use of a paper coated with a thin stratum of albumen and rendered sensitive to light by a salt of silver. Photographs so produced are liable to gradual spontaneous decay, and fade away to the pale ghosts of their former selves, and ultimately disappear.

Autotype claims permanency for its *raison d'être*. The difference it imparts into photographic printing consists principally in substituting for the fickle salts of silver some permanent pigment as the physical basis of the picture. This substitution not only supplants the evanescent by what is practically inalterable, but endows photographic art with the wide range of monochromic effect. Photography in natural colors is still a dream, but autotype is able to make some slight advance towards art in this direction. The process is founded on the property of gelatine when combined with a bichromate salt to become insoluble in water after having been exposed to light. Paper is coated with a film of liquid gelatine containing finely ground color and sufficient of the bichromate salt to insure chemical action. This sensitive tissue, kept from the light, is perfectly soluble in water; but if light acts upon it the whole condition is altered: the gelatine becomes insoluble, and firmly imprisons every particle of the coloring matter. It will now be understood that if this sensitive tissue be placed under a negative and exposed to light, the chemical action exerted upon it will be in proportion to the density of the negative; where much light passes, the tissues will be deeply penetrated and much color imprisoned; where the light is partially intercepted less color will be fixed, and a latent picture will be formed in the tissue in exact gradation, and with the lights and shadows as in nature.

To make this latent picture visible, it is, in technical language, "developed" by the action of warm water, washing away such portions of the colored gelatine film as have not been influenced by light. But effective development is only possible by an ingenious operation known as "transfer." The impact of light through the negative on the surface of the tissue has rendered that surface insoluble, and to achieve success the pictorial film must be attacked at the back, that is, at the surface resting on its paper support. The various methods of effecting this constitute an important part of the autotype patents.

The sensitive tissue which under the negative becomes fecundated by light is called the "temporary support," and the surface of this is made to adhere by pressure to the material on which the picture shall finally remain. This "permanent support" may be drawing paper, canvas, panel, ivory, or, in fact, almost any material used by artists. The two adhering supports are immersed in warm water, which softens the gelatine and allows the original paper or temporary support to be peeled off, and thus lays bare to the action of the water all the pig-

mented gelatine unaffected by the light. Under the solvent action of water the picture gradually appears and remains firmly adherent to its support. The lights and shades of this picture are built up by various degrees of thickness in the gelatine and pigment, representing exactly the gradations of density of the original negative and the consequent modifications of the action of light. The developed pictures, after being immersed in a solution of alum, washed in pure water and hung up to dry, are trimmed and mounted in the usual way. Such photographic pictures consist of particles of pigment held together by an incredibly thin film of gelatine, rendered insoluble by chemical agency. —*Art Journal*.

Causes of Injury to Cables.—The teredo has been very destructive in its attacks upon the gutta-percha coating of submarine cables. Sharp-toothed fishes have often interrupted the communication between Chyenne and Para. Turtles have attacked the wire from Key West to Havana. A whale broke the cable in the Persian Gulf, and lost its life by getting entangled in the wire. Lightning has destroyed one or two of the Mediterranean cables. In some places submarine currents have worn out the cables by friction against the rocks; in others they have broken by their own weight in spanning ocean valleys. The attacks of insects have been partially overcome by mixing poisonous ingredients with the gutta-percha. —*L'Electricité*. C.

New Pendulum Experiments.—M. Dejean de Fourouque has experimented with a pendulum, vibrating in a large arc and free to move in all azimuths. He finds that the plane of oscillation tends rapidly to assume a special direction, which is, according to his views, the horizontal projection of the earth's trajectory, or, in other words, the resultant of the two great movements towards the constellation Hercules and around the sun. The path traverses the meridian four times a day, and the hours of crossing vary with the position of the earth in the ecliptic. M. A. Corwin has witnessed the experiments and reported them to the French Academy. Although he hesitates to adopt Fourouque's conclusions with regard to the cause of the movements, he thinks them so interesting and important that he recommends them to the careful study of physicists and geometricians. —*Comptes Rendus*. C.

Fossil Oak.—A sunken oak forest, of great extent, has been lately discovered in the neighborhood of Rothenburg, on the Fulda, in Hesse-Cassel, from two to three meters (6·562 to 9·843 ft.) below the surface. It appears to have been submerged in prehistoric times, in consequence of heavy freshets on the Fulda. Some of the trunks are of truly colossal dimensions. The wood is coal-black and extraordinarily hard.—*Fortsehr. der Zeit.* C.

The Navisphere.—M. de Magnac has submitted to the French Academy an instrument for navigators, to which he gives the name of navisphere. It shows the stars which are above the horizon at any given moment, and determines their altitudes and azimuths within about 1° . It also shows, with the same approximation, the proper course for great-circle sailing from one point to another, and the distance between those points within about $\frac{1}{4}$ of 1° . It gives a ready practical solution of spherical triangles. It has been tried upon the *Washington*, of the Transatlantic Company, with such favorable results that it seems likely to come into general use. [It would be interesting and desirable to subject it to comparative tests with Dr. Thomas Hill's Nautricon.]—*Comptes Rendus.* C.

Transmission of Force by Electricity.—In an extended communication "On the transmission and distribution of motive power to a great distance by means of electricity," M. A. Achard cites experiments of MM. Higgs and Brattle, and of E. Hagenbuch-Bischoff, Professor of Physics in the University of Basle. The gentlemen first named used Siemens' machines, and found a maximum efficiency of from 39 to 49 per cent. when the rotating velocity of the receiver was about half as great as that of the generator. M. Hagenbuch-Bischoff experimented with a Gramme machine, and reported efficiency of from 65·9 to 93·5 per cent., the force being increased by the aid of a brake, a method which Achard thinks objectionable. He recommends systematic experiments for the following purposes: 1. To ascertain, for many types of induction machines, and for the principal varieties of each type, the relation between the intensity of the current and the magnetism of the induction magnets, and to seek an empirical formula for representing the relation. 2. To determine the rendering of the different induction machines when acting as generators. 3. To determine the rendering of the same machines when acting as motors.—*Ann. des Mines.* C.

Sinus-Manometer.—Julius Thomsen, of the University Laboratory in Copenhagen, has contrived a new manometer for the measurement of slight differences of pressure, to which he gives the above name, because the difference of pressure is proportional to the sine of the angle of deviation in a small pendulum. By its aid it is easy to observe a difference of a difference of pressure equivalent to a column of air 1 millimetre (.039 in.) high, or of a column of water $\frac{1}{740}$ of a millimetre ($\frac{1}{19600}$ of an inch) high, a degree of delicacy hitherto unknown. It can also be employed as a gas regulator, or as a governor of ventilating currents.—*Ann. der Phys. u. Chem.* C.

Prediction of the Microphone.—In her work on the "Physical Basis of Immortality," published in 1876, Antoinette Brown Blackwell said: "It remains to invent some instrument which can so retard the too rapid vibration of molecules as to bring them within the time adapted to human ears; thus we might comfortably hear plant movements carrying on the many processes of growth, and possible we might catch the crystal music of atoms vibrating in unison with the sunbeams. Sound can be refracted by passing it through a lens which retards its motion. Such an improvement upon the stethoscope would reveal phenomena but little more marvellous than those already offered us by the telescope and microscope."—*Woman's Journal*. C.

Electro-magnetic Tests of Steel.—Dr. A. von Wattenhofer presented a communication to the Vienna Academy in 1863, in which he gave an empirical formula for the relation between the strength of a magnetizing current and the resulting magnetic moment of a steel rod. The formula contained a coefficient which furnished a ready means for estimating the hardness of any given sample of steel. In 1878, A. von Kerpely criticized the theory and methods, but without sufficient care in his experiments. Von Wattenhofer, in his reply, describes a delicate balance (which can also be readily used for weighing letters), and shows the importance of maintaining constancy of current. In all comparisons it is necessary to have all the circumstances as nearly alike as possible, and to avoid any initial or residuary magnetism in the rods which are subjected to trial. If proper precautions are observed, he claims that the results will be more consistent and satisfactory than can be obtained in any other way.—*Dingler's Journal*. C.

SCIENTIFIC SPECIALTIES.

VIENNA ACADEMY OF SCIENCES, Jan. 16, 1879. Pre-historical investigations in Lower Austria, Carniola and Bohemia, by F. v. Hochstetter.

ROYAL SOCIETY, London, May 29. Note on the spectrum of sodium, by J. Norman Lockyer. The metal, after slow distillation in a vacuum for some time, shows the red and green lines without any trace of the yellow one. Hydrogen is given off in large quantities; and at times the C line and the red "structure" are seen alone. After this treatment the metal, even when red hot, volatilizes with great difficulty.

LINNEAN SOCIETY, May 1st. A paper by Thomas Meehan gives observations from which he deduces the conclusion that the struggle for power between the vegetative and the reproductive forces decides fertility.

ANTHROPOLOGICAL INSTITUTE, May 13. Ethnology, mythology and philology of early civilized races, by Hyde Clarke.

FRENCH ACADEMY, May 26. Refraction of obscure heat, by M. Desains. Determination of calorific wave lengths, by M. Mouton.

IMPERIAL ACADEMY OF SCIENCES, Vienna, March 20. Relation between heat radiation and temperature, by Prof. Stefan. Chemical composition of pyroxilin and formula of cellulose, by Prof. Eder. April 3. Polar actions of the electric current in striated muscle, by Prof. Hering. Ditto, in muscles deprived of nerves, by Dr. Biedermann.

ROYAL SOCIETY, May 15. Capillary phenomena of jets, by Lord Rayleigh.

FRENCH ACADEMY, June 2. Ultra violet limit of the solar spectrum, by M. Cornu. Production of Widmanstaetten figures on artificial iron, by Prof. Lawrence Smith.

MONITEUR SCIENTIFIQUE, June, 1879. Influence of change of temperature upon the deviation which inverted sugar produces upon polarized light, by Paul Casamajor. Acceleration in the tanning of hides by means of phosphoric acid, by E. Ador. Use of anhydrous chloride of calcium for preserving steam boilers, by M. Burstyn.

CHEMICAL SOCIETY, June 5. On chlor-stannic acid, by J. W. Mallet. A bottle containing a strong solution of stannous-chloride, after standing for a year, deposited a transparent jelly-like substance, which proved to be SnO_2HCl .

PHYSICAL SOCIETY, May 24. New induction balance, by Prof. Hughes.

AMERICAN ACADEMY OF ARTS AND SCIENCES, May 14. Two new proofs of the dimensions of molecules, by N. D. C. Hodges. New form of photometer for measuring the light of a nebula or comet by comparison with a star thrown out of focus, by Prof. Pickering. The method employed eliminates the effects of moonlight or twilight. New method of studying wave motion and vibrations on the surface of mercury, by Prof. John Trowbridge.

GEOLOGICAL SOCIETY, June 11. Further discoveries in the Crosswell caves, by Boyd Dawkins and J. M. Mello.

PHYSICAL SOCIETY, June 14. Plan for suppressing the induction disturbances in a telephone circuit, by Prof. Macleod. Experiments on the sensitiveness of electric discharges in vacuum tubes, by Moulton and Spottiswoode. Traces of oxygen and carbon in the sun, by Dr. Henry Draper and J. Norman Lockyer. Mr. Lockyer congratulated solar science on having so able a worker as Dr. Draper.

FRENCH ACADEMY, June 16. Influence of media on the structure of roots, by M. Mez. Modifications in the apparent color of flowers by the electric light, by M. Hugo.

SILLIMAN'S JOURNAL, July. New form of spectrometer, and distribution of the intensity of light in the spectrum, by J. W. Draper. Progress of experiments for comparing a wave-length with a metre, by C. S. Peirce.

LONDON E. AND D. PHIL. MAG., July. New theory of terrestrial magnetism, by Profs. Perry and Ayrton. On electric boundary layers, by Prof. Helmholtz. (From the February Monatsbericht of the Berlin Academy.)

DONATIONS.

Annales du Génie Civil, ou Recueil de Memoires sur les Ponts et Chaussées, etc. Paris: E. Lacroix, 1862 to 1871 inclusive. 28 vols. Plates.
From Lewis S. Ware.

Souvenirs de Marine Conservés, ou Collection de Plans de Navires et de Bateaux de tous les pays. Par l'Amiral Pâris. 1877.
From the Author.

Annual Report of the Chief of Engineers. 1878. In three parts.
From the Chief of Engineers.

Chronological History of Plants. By Charles Pickering. Boston, 1879.
From Mrs. S. S. Pickering.

Fiftieth Annual Report of the Board of Commissioners of Public Schools of Baltimore for 1878.
From H. E. Shepherd, Sup't of Instruction.

Improved Dwellings for Laboring Classes. Pamphlet on.
From R. Grimshaw.

Memorial Address upon the Character of Morton McMichael. By J. W. Forney.
From the Author.

Croft's New Overland Tourist and Pacific Coast Guide.
From E. A. Croft.

Mechanical Refrigeration. Part 14. By J. J. Coleman, of Inst. of Engineers and Shipbuilders in Scotland. Glasgow, 1879.
From the Author.

Abstracts of Papers in Foreign Transactions and Periodicals. Excerpt Min. of Proceedings Inst. of C. E. London, 1879.
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ARTIFICIAL FUEL MAKING IN EUROPE.

By ROBERT GRIMSHAW, PH.D.

The "briquette" or block of compressed coal, as generally used in Europe, is composed of fine coal dust, with a "bond" or cementing substance of pitch. This fine coal, often of different kinds, as fatty or poor coal, lignite, etc., comes to the briquette factory sometimes washed, sometimes unwashed; and containing a certain proportion of ash; and the mixture of these various kinds, in proportions determined beforehand, or even varying during the course of manufacture, gives a fuel suited to the needs of various industries.

The pitch is the residue of distillation of coal tars; it is employed in the solid state, broken in particles about the size of those of the coal it is to agglomerate, and it acquires its cementing properties at a temperature of about 80° to 100°C . (176° to 212°F .).

Before speaking of the briquette machine proper, it will be well to describe rapidly the successive operations entering into the manufacture of compressed fuel, as carried on in Europe, and the auxiliary machinery used therein.

The pitch is broken (often indeed, pulverized); then the different kinds of fine coal are weighed and proportioned; and all, coals and

pitch, are immediately mixed—and in some establishments reduced at the same time to a homogeneous powder.

This mixture is gradually brought by steam jackets or jets to the temperature necessary for the agglomeration to take place, is next put into a mould and highly compressed, then extracted from the mould and shipped.

All these operations are done mechanically (although at the celebrated establishment of Monsieur Decauville *ainé*, at Petit Bourg, Seine et Oise, the moulding is done by a hand tamper, as the blocks are small, are not subjected to a rough usage and are used at once at the place of manufacture). The workman has but to superintend the lubrication and general working of the machines.

The machines are :

(1). *The pitch mill* ; about like an immense coffee-mill, and composed of two truncated cones of cast iron, one solid, the other hollow ; the latter fixed, the former movable, and both armed with projections or teeth, which break, between them, the pieces of hard pitch. The broken pieces are, of course, of a degree of fineness, depending upon the distance between the two cones, this being adjustable.

In some establishments a complete pulverization is required ; and then the pitch passes from the conical mill into a “ Carr ” disintegrator. This machine is a very well known concussion disintegrator, unnecessary to describe here. There are modifications of it made in this country, which should answer equally well.

The proportioning of the pitch is done in a *measurer*—a cast-iron cylinder box having a horizontal axis, and partially closed at one end, while open at the other ; in this there turns, on the same axis, an endless screw of cast-iron, taking up the material entering by the closed end and pushing it out at the other. This box is surmounted by a hopper kept full of material ; and it is easy to see how the quantity of pitch distributed at each revolution of the screw corresponds with a constant volume, depending on the diameter and the pitch of this screw. Belts and conical pulleys give different speeds, and thus enable the quantity and proportion of pitch to be changed, even while the machine is in motion.

The various kinds of coal are weighed out in proper proportions, and mixed in a special measurer ; so that the coal and the pitch leave their respective measurers in suitable proportions, and arrive, by sheet-iron troughs, in the hopper of a Carr disintegrator of great diameter,

which turns at a moderate speed, and effects an intimate mixture of the materials, without pulverizing them too much. In small establishments the mixture is effected in cylindrical sheet-iron hoppers in which the material is pushed by arms fixed on an axis of rotation, and approximating in their arrangement and effect the action of a screw.

The products arrive, mixed, in a trough; and a belt and bucket elevator, or a "*noria*," takes them up and discharges them into the mixer of the compressor, or the briquette machine proper.

It is also by means of endless chains that the coal and the pitch are taken from each of the preceding apparatus to the one following, when these are installed on the same level; but these organs can be suppressed by so arranging the establishment, as in a sugar refinery, that the materials descend by gravity in successive cascades, as it were.

The briquette machine of the "*Société Nouvelle des Forges et Chantiers de la Méditerranée*" is shown in two sections, in Fig. 1.* It is a modification of the Mazeline and Cody compressing machine, well known in Europe in this industry. By the Patent Office classification it would, as now built, be considered as a duplex hydraulic machine, with horizontal mould-tables, continuous moulding and successive production.

It differs from the old type of machine—

1st. In consisting of two separate machines, which can be worked either or both at will, thus permitting one to work at normal belt speeds on half production.

2d. In employing hydraulic pressure. Thus, while in the Mazeline machines the compression is by steam pistons acting on a lever, and reaches a maximum of 90 kilogrammes per square centimetre (say 1200 lbs. per square inch) of horizontal section of the briquette—it varies in the new machine from 100 to 300 kilogrammes per square centimetre of the same section, and without recourse, as we shall see later, to the special pumps, accumulators, etc., which accompany hydraulic machinery of all kinds.

This agglomerating machine consists of:

1st. A *mixer A*. This is a large vertical wrought-iron cylinder in which the materials are brought gradually to a temperature suitable for agglomeration. It is composed of a double envelope in which circulates steam, which keeps the walls at a high temperature. On the same axis, as the cylinder turns continuously, a vertical shaft, armed with

* Taken from *Engineering*, November 8th, 1878.

blades, *aa*, which divide the materials, mix them and knead them. Jets of steam are let in at the same time by openings shaped like rose sprinklers, and so placed on the walls as to surround the materials on all sides during the mixing, and to heat them by giving up all the very considerable heat (530 calories). When the material appears sufficiently hot or agglomerant (which the workman can readily see by taking some in a shovel and pressing it with his hands), he opens two doors, *bb*, in the lower side, and the material falls into the distributing apparatus.

2d. *The Distributor*. This serves to distribute the paste into the moulds. It is composed of a cast-iron chamber, in which turns a rake or scraper, of which the arms *c* sweep the material into the moulds, which pass under the distributor and are there completely and uniformly filled.

3d. *Moulding and Discharging Apparatus*.—One on each side of the filler, and under it, are two rotating "mould-tables," which are heavy disks or plates of cast-iron, bearing on their plane faces, near their circumferences, a circle of angular recesses, faced with steel and corresponding to the form and dimensions of the block or "briquette" desired. These mould-tables have an intermittent motion upon a vertical axis, forming part of the bed-plate of the machine, and carrying with them rectangular compressing blocks or pistons placed in the recesses or moulds. These blocks rest upon and slide on horizontal, circular inclined planes, *f*, which form part of the foundation of the machine, and which give to the blocks a rising and falling motion in the moulds.

Following one of the moulds during a revolution, we note that the mould-table is stopped when each mould is under the distributor; and in this position of mould the piston is at the bottom of its course, and resting on a horizontal plane. The material, pushed by the scraper of the distributor, fills the mould completely. The rotating mould-table starts off and then stops—the mould is still under the distributor; the piston block has slid along the horizontal part of the track, in case the mould were not perfectly filled at the first stoppage, the filling continues and is surely finished. At the next movement of the mould-table, the mould passes under a compression surface, *D*, the block mounts the inclined plane and thus lightly compresses the paste. This "initial compression" is highly advantageous, bringing the paste to a compact condition, and in the case of moist coals (most coals are moist),

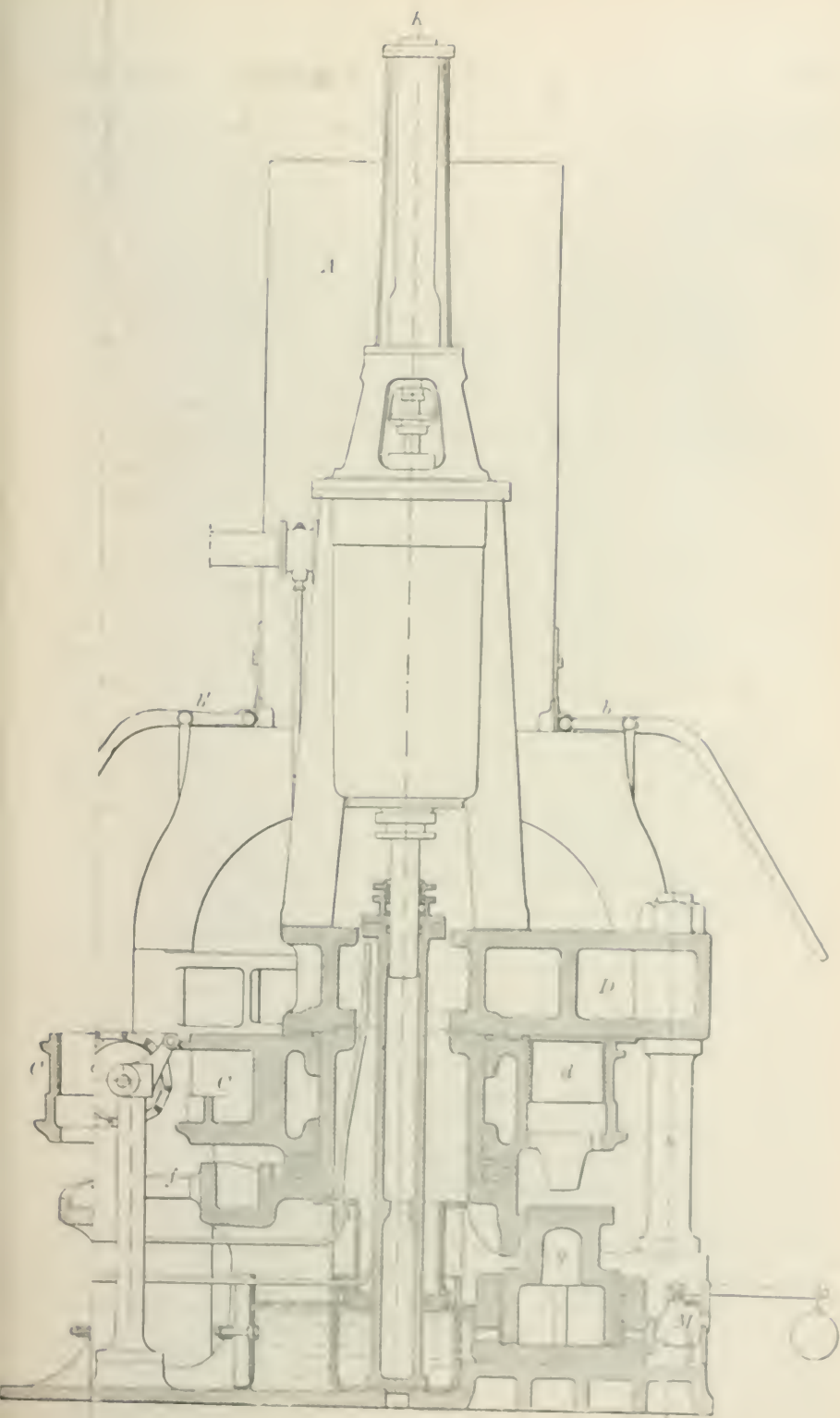
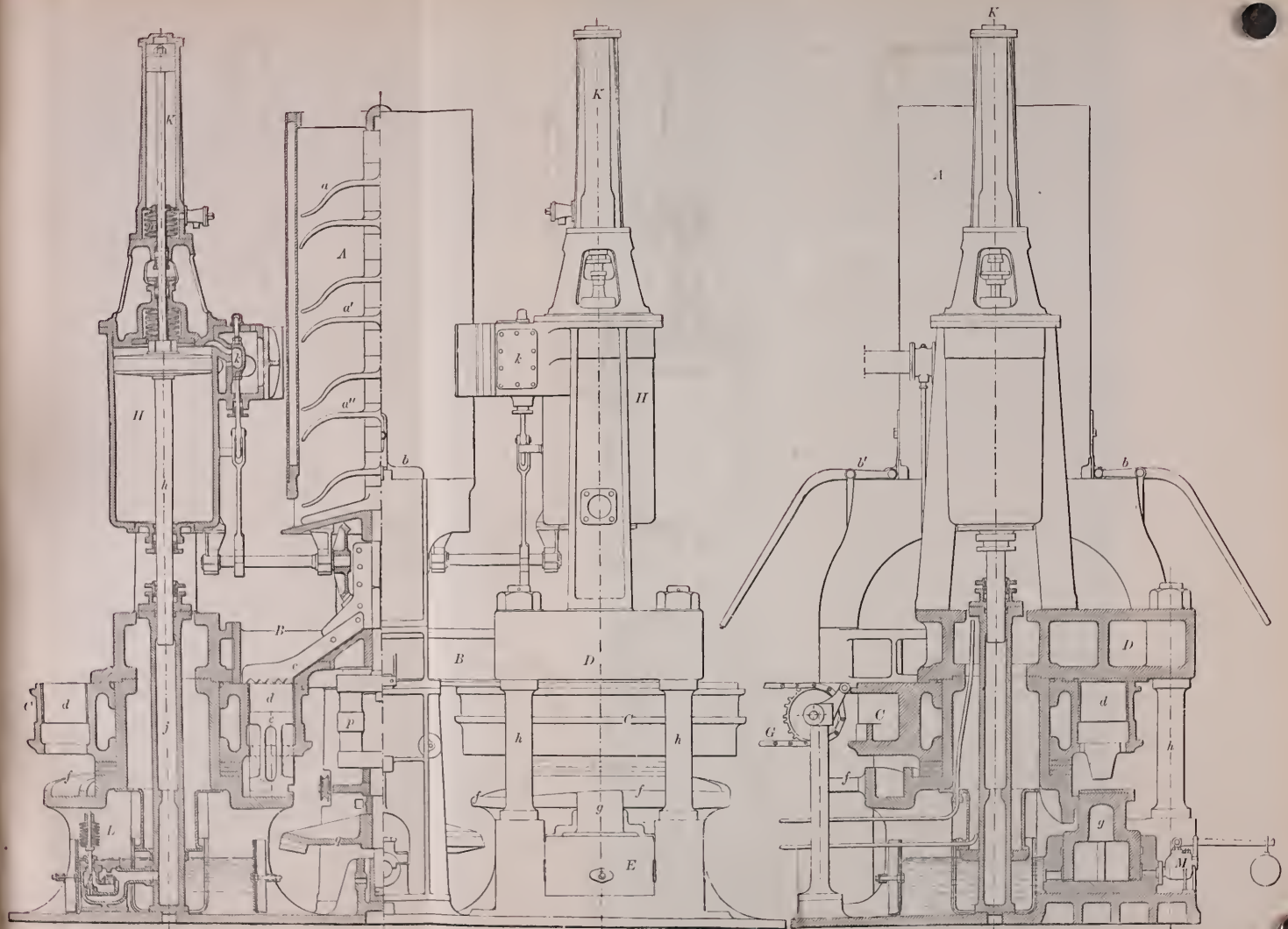


FIG. 1.



expressing most of the water. It also saves a good deal of the power required for the heavy compression, as in using the full force of the machine, to effect light work only, much force would be wasted.

The mould rests under the compression-table, and the block completes the initial compression by finishing the ascent of the inclined plane, and then passes on to a horizontal plane or track on the level of the hydraulic press. In the next movement of the intermittently rotating mould-table the piston-block passes under the press or ram, *E*, and during the next time of stoppage is forced in by the plunger, *g*, thus powerfully compressing and agglomerating the paste.

The intermittent movement of the mould-table continuing, the mould comes from under the compression plate, the block piston mounts a second inclined plane and raises the finished briquette in the mould; so that by the time the table has made a semi-rotation the block is entirely free from the mould, and a "mechanical hand" takes it off the table and puts it on an endless chain, *G*, to be carried away.

4th. *The Compressor.* This essential part of the machine consists of a compression plate *D*, held by strong wrought-iron pillars or bolts, *h*, to the foundation plate and to the steam and hydraulic cylinders which produce the compression.

The cylinder *H*, above the compression table is a steam cylinder, its piston rod, *h*, serving as the plunger of a hydraulic pump, *I*, resting on the bed-plate. In communication with the pump is the hydraulic ram or press, *E*. Above the steam cylinder and on the same axis is a cylinder of lesser diameter, *K*, having its lower end always in communication with the steam supply pipe, so that there is a constant pressure tending to keep the steam and pump pistons at the upper end of their stroke, and the press-ram at lower course.

The steam cylinder is supplied with a steam chest and a slide-valve, *K*, actuated by an eccentric, having a motion proportioned to that of the intermittently rotating mould-table. As each mould-block stops under the press the slide-valve opens the admission port, and the steam, acting on the upper face of the piston, drives the steam and pump pistons down, and the water pressure transmitted to the ram causes the compression. The slide-valve then shuts the steam ports and opens the exhaust port; the piston of the small steam cylinder raises the system to its first position. Between the pump and the hydraulic press is a valve box, *L*, containing two clappet valves—one, *l*, held in its

seat by adjustable springs, and the other, *m*, able to lift freely and let the water return.

The water forced by the pump lifts the spring clappet before acting on the press, so that in case the distribution of the paste in the moulds is stopped or incomplete, and in consequence the effect of compression is suppressed or reduced, the resistance experienced by the water in lifting the clappet prevents too rapid a movement of the pistons and plungers from causing shocks. The return valve permits the water to pass freely from the press to the pump in the next movement. It is easy to understand that this disposition renders the movements of the organs of compression independent, in a great measure, of the regularity of distribution of the materials in the moulds. In case the pistons arrive at the end of their stroke with some considerable speed, as always takes place at the upper end of the stroke, their momentum is taken up by spring buffers, *n*, *o*, in the upper part of the large steam cylinder and the lower part of the little one.

Another part of the compressor is a valve box *M*, communicating with a water tank and containing a safety valve held by a weighted lever, and which valve is lifted when the pressure of the water in the hydraulic press passes any given limit. There is a second or suction valve, which allows water to pass from this tank into the hydraulic pipes to compensate for losses.

5th. *Organs of Movement or Driving Parts.* The intermittent motion of the rotating mould tables is produced by two pawls acting on cast-iron teeth on the crown of the mould tables and corresponding with the moulds; these pawls are actuated by the connecting rods of a crank shaft *p* so that each turn of the axis causes motion of one table and rest in the other. The crank shaft is driven by bevel wheels *q* and a pulley.

The auxiliary apparatus have (as has the main machine) fast and loose pulleys and proper striking gear, and they receive motion from the main driving shaft of the factory. All the transmission is by means of belts, and the tension and the belt lacings or fastenings are arranged so as not to exceed in strength a certain limit; so in case the apparatus is stopped by the presence of a foreign body in the coal or in the pitch, the belt breaks or slips and no damage is done. There are of course necessary the suitable boilers and driving engines.

I gave above the degree of compression which could be obtained; here is a table of the production for twenty-four hours of the different

sizes of this apparatus, the sizes being named after the weight of the blocks produced. It is not very necessary to remind one that the single machine has but one mould table.

Size of machine or Weight of blocks.				Production in 24 hours	
	kilogrammes	=	lbs.	Single.	Double.
10'		=	22	290 tons.	580 tons.
5'	"	=	1.1	160 "	320 "
2.5	"	=	0.55	86 "	170 "
1.25	"	=	0.275	48 "	96 "

The machine described compresses its own water as required, but it is evident that if it were desired one could utilize a natural head of water or draw the water from an accumulator or from any other source of liquid under pressure. In this way the steam cylinders and the pump are omitted, the hydraulic press being retained and supplied with a distribution chest having a suitable slide valve.

FIG. 2.—Curve of Steam Cylinder.
Scale of pressures, 7 mm. = 1 kilog.

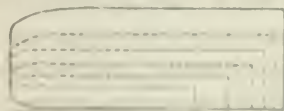


FIG. 4.—Curve of Steam Cylinder.
Scale of pressures, 3.5 mm. = 1 kilog.



FIG. 3.—Curve of Hydraulic Press.
Scale of pressures, 0.7 mm. = 1 kilog.

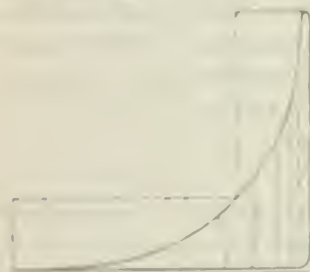


FIG. 5.—Curve of Hydraulic Press.
Scale of pressures, 0.7 mm. = 3 kilog.



I shall now give an account of some experiments made for the "Société des Forges et Chantiers," by Mons. Pierre Sigaudy; with the conclusions to which he was led in the direction of economy of steam and of water in the apparatus just described. Mr. Sigaudy has made indicator-curves showing simultaneously the work in the steam cylinder and the resistance in the hydraulic press.

Figs. 2 and 3 show a series of mean curves obtained with a paste

and general conditions giving good products; and the dotted lines show curves sensibly approaching those obtained with feeble pressures, but on the same paste.

Figs. 4 and 5, as well as the dotted lines, show a second series of curves obtained with a "leaner" paste, that is to say one containing less pitch, and, in consequence, requiring more pressure.

The working pressure is proportional to the rectangular surface 2 and 4, and the resistance to the surface of the curves of 3 and 5. It is easy to comprehend that on the scale of the curves 3 and 5 the working forces could be represented by rectangles having for sides the maximum abscissas and ordinates of the curves; admitting what is theoretically exact and sufficiently verified in practice, that at the end of the stroke the total pressure in the steam cylinder and in the hydraulic press are in inverse proportion to the space traversed.

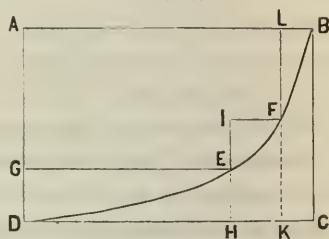
The general appearance of the two curves is the same; but the laws of the variations of pressure are different.

Without going into the cause of this difference, depending, evidently, on the compressibility of the paste, we can lay it down that the ratio of the resistance to the force expended is very feeble; and the "Société des Forges et Chantiers" thought that there was need to improve their new apparatus in order to get better economic results.

In studying the problem from a general point of view, let DC , Fig. 6, be the stroke of the hydraulic press; and CB the constant pressure of the inflowing water. The rectangular surface $ABCD$ represents the work expended; and the surface of the curve-diagram $DEFBC$, the resistance. The ratio of these two surfaces, $\frac{DEFBC}{ABCD}$ will be the duty of the machine.

We shall obtain the same work of compression if we replace the constant pressure CB at first by a feeble initial pressure DG , then when the ram has traveled the space DH , by a second pressure HI , and finally, after the course DK , by a pressure KL . The work expended in this case will be equal to the surface of the three rectangles $DGEH$, $HIFK$ and $KLBC$; and it is easy to understand that in this way the duty of the machine will be greatly increased,

FIG. 6.



and would be still further increased by increasing the number of successive pressures.

The mechanical arrangement by which this is proposed to be effected by the "Société des Forges et Chantiers" gives two successive and increasing hydraulic pressures, independent of the initial wedge-pressure given by means of the inclined plane.

The economy of steam resulting from this arrangement is considerable. In making the calculations from the curves, based on a pressure of 50 kilogrammes per square centimetre, the weight expended per stroke of piston is $\frac{1}{2}$ that to obtain the same result with a single pressure; and for a pressure of 100 kilogrammes per square centimetre (say 1375 lbs. per square inch), the expenditure is reduced to 20 per cent. of that indicated by curve 4; that is to say, a mean economy of $\frac{2}{3}$ the steam.

The new machine is represented in section and elevation in Figs. 7 and 8. In comparing it with Fig. 1, we see that the *two* steam cylinders (the compression cylinder and the auxiliary steam cylinder) are replaced by a single steam cylinder *A*, of which the piston carries an expansion joint *a*, and which receives the steam by a double ported slide valve *b*. The plunger pump is replaced by a piston pump *B*, having a valve chamber *C*. Finally, for the buffers in the steam cylinders, there is substituted a single box containing a rubber block *D*, in full sight and controllable while the machine is running.

The section of the pump piston is such that with the steam acting above the steam piston, the pressure of the water under the pump piston corresponds to the first rectangle in broken lines. The section of the pump piston-rod is such that the pressure of the water in the pump will be the maximum desired, if this steam acted as the plunger of a hydraulic pump. This pump is in communication with the hydraulic press by the passage *C*.

Suppose the steam admitted by the upper port of the slide valve, the pump piston descends and compresses water in the press at the first pressure. At the same time the space which would otherwise be left void above the pump piston, is kept full by means of a valve *d* in communication with a supply tank.

As soon as the resistance of the press passes what we should call the first pressure (that is, the first *hydraulic* pressure) on the paste, the valve *e*, held by a suitably adjusted spring, opens; the water, under pressure (I object to the use of the expression *compressed* water) passes

FIG. 7.

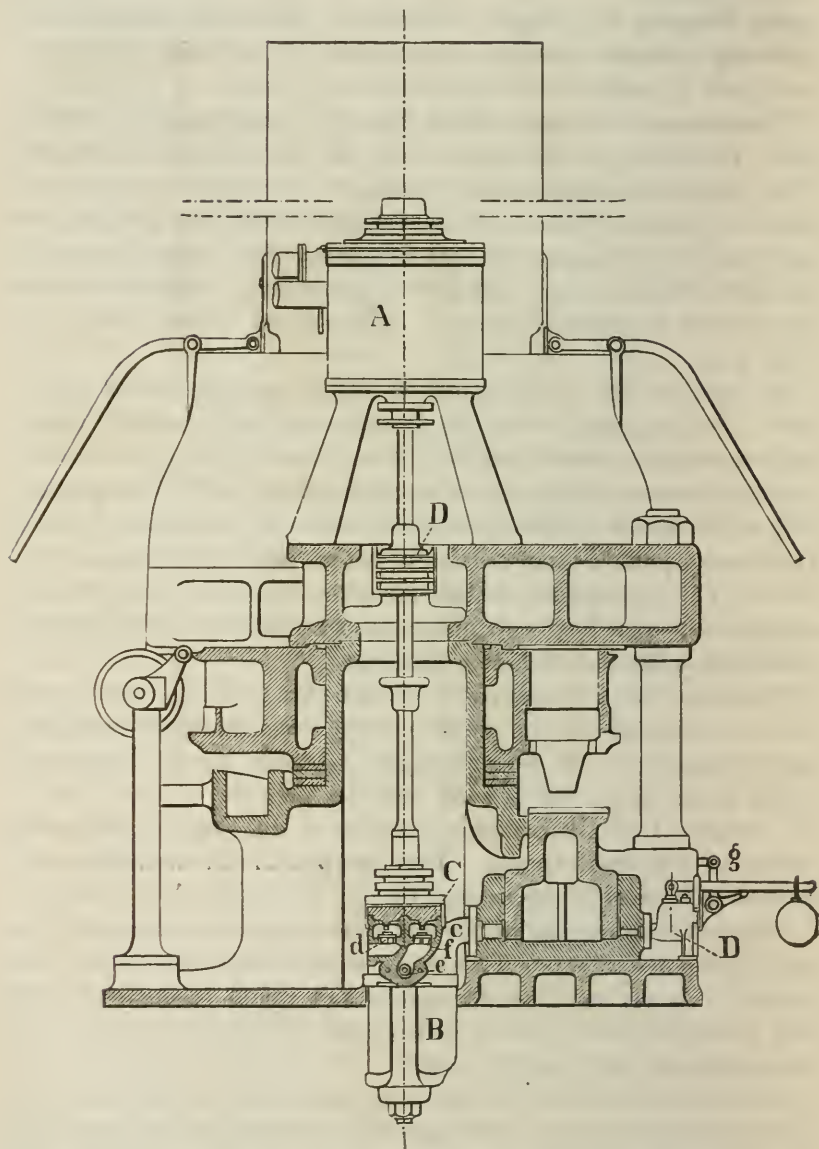
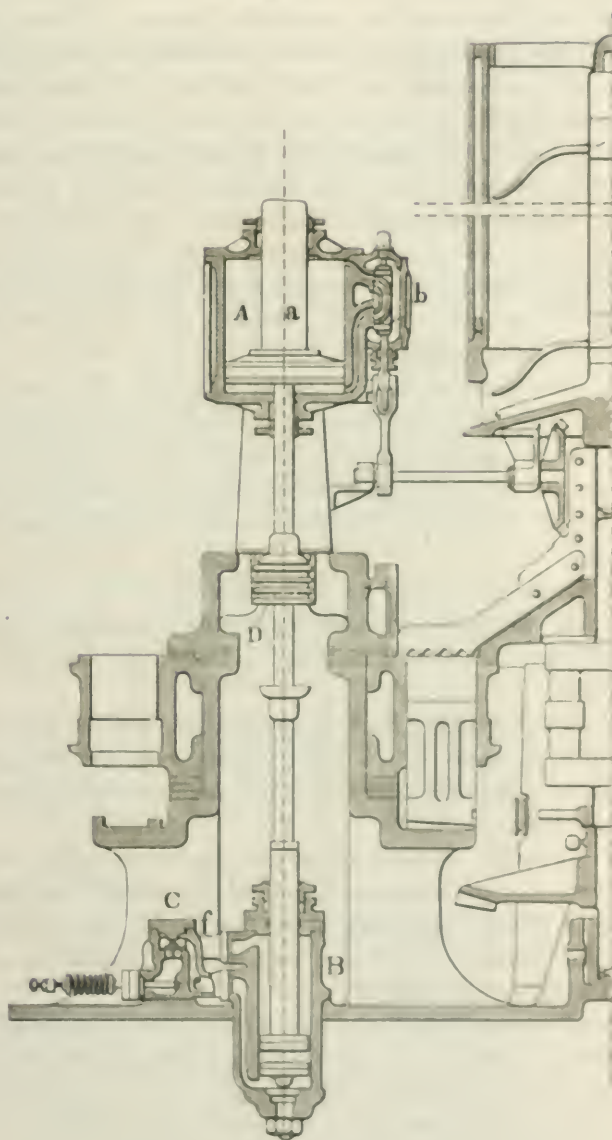


FIG. 8



in part from the other side of the piston, shuts the suction valve *d*, and we have the conditions of a hydraulic pump having a plunger of a diameter equal to that of the piston-rod. The compression is thus continued with this second or maximum pressure. When the resistance of the press attains this maximum, the safety-valve *D* opens, the press stops, and the compression is held until the slide valve closes the steam port and puts the upper part of the steam cylinder in communication with the lower; the steam piston is then raised to the upper end of its stroke by a pressure due to the difference in areas of the two piston surfaces. The pump piston is thus raised; the water passes from the upper to the lower side by the valve *f*. Part of the water in the hydraulic press also returns under the pump piston, the rest being discharged by the safety-valve *D*, which is for this purpose raised by the lever *g*, suitably actuated.

It is nearly useless to add that by tightening the spring of the valve we increase the initial pressure, and thus we can so control the disposition of the partial rectangles upon the curve representing the resistance on the hydraulic press, as to effect the greatest convenience and economy in work, and to adjust the machine to the material it may be working.

In the case of the briquette machine supplied by a constant head of water, and to which I referred above, the arrangement adopted by the "Société des Forges et Chantiers" is based upon the same mechanical principle.

The steam cylinder is of course omitted, and the hydraulic press, as described, is replaced by a double-acting press, the two parts of which are put in communication by a valve chamber with a spring poppet and a return valve.

In conclusion, we must admit that this new machine responds to the actual needs of the compressed fuel industry already; so large and flourishing in Europe, and destined to effect in our own country the practicable and profitable solution of an important economic problem, "What to do with the coal dust."

By the machine shown in Fig. 1 the cost of manufacture, in France, per 1000 kilogrammes or one ton of briquettes may be thus distributed:

STEAM corresponding to 70 kilogrammes of coal consumed.

CULM, 930 kilogrammes. PITCH, 70 kilogrammes.

LABOR, 1f.50 = 30 cents; in time, 3 hours.

LUBRICATION, f0.50 = 10 cents.

The above mentioned items are greatly lessened in the machine shown in Figs 7 and 8.

WEAR AND TEAR and MAINTENANCE, 7 per cent. per year on cost of plant.

INTEREST, 5 per cent. annually on cost of plant. (For America say 6 per cent.)

THE FLEXIBLE SHAFT.

By GEORGE BURNHAM, JR.

There is probably no mechanical invention of the last decade that has seemed, not only to the casual observer but also to the mechanician, to be so entirely novel in its character as the flexible shaft. Great strides have been made during this period, it is true, in all kinds of machinery, but the expert recognizes most of them as extensions and developments of known ideas and methods. So radically different, however, were the principles involved in this tool from those usually employed in machinery, and so unobserved by the world at large had been the stages of its evolution, that when exhibited at the Centennial Exhibition every beholder was struck with astonishment. Almost all machinery is characterized by fixity in certain planes of motion. The whole value of the turning lathe is conditioned upon the maintenance of its centres in a true line, and in all reciprocating machine tools, as planers, shapers, slotters, etc., and also in milling tools, the moving portions of the mechanism are confined to fixed lines and planes. Accustomed as we are to this characteristic of machinery, a device that transmits rotary motion, not through straight lines but through curves, and curves that may be varied at will, is naturally surprising when first seen.

The Paris correspondent of the *London Times*, writing of the Exhibition of 1878, and referring to the flexible shaft, correctly expresses this feeling when he says " * * * it upsets all one's ideas of rigidity. Pharaoh himself could not have been more surprised at seeing Moses' rod turn to a serpent than we were to see this rope-like affair eating into the planks set on all sides for it to work upon." And yet, like all inventions, it has had its history of gradual development from crude beginning to more or less perfect consummation.

The first "flexible shaft" was simply a coil of wire. This was used as a universal joint in sheep-shearing machines, dental engines, and

other light power machines. In the reports of the Paris Exhibition of 1867, however, will be found a description of a Belgian windmill involving a shaft of this character, made of rectangular steel bar, about $\frac{1}{4} \times 1\frac{1}{4}$ ", coiled into a spiral spring, some six inches in diameter. The limitations of this form of the device are quite evident. The flexibility was obtained at a great sacrifice of strength, to compensate for which the coil had to be made of inconveniently large diameter, about six inches, as above stated, making it equal to a solid shaft of one and one-third inches diameter only.

It was soon found that the angle of torsion was so great in the single coil shaft that it could not be used where positive motion was desirable. One of the first attempts to correct this defect was made in January, 1865, a patent of that date,* describing a shaft made of a coil of wire wound on a centre of "gum elastic or rolled canvas, or other flexible material." This, of course, was an improvement over the first form only to the extent of the resistance to compression offered by the filling material. The next step, one of great importance, was the substitution of two concentric coils, wound in opposite directions, for the single coil heretofore employed.† By this arrangement the tendency of the outer coil to contract is met by an equal effort of the inner coil to *expand*, while the greater metal section of course increases the strength of the shaft.

It will be seen, however, that some of the flexibility is lost by this construction, since it requires more effort to bend two coils than one.

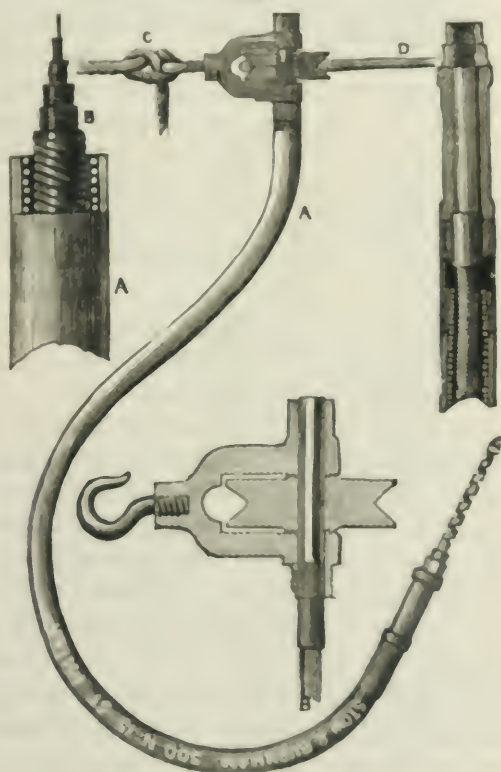
Up to, and including this stage of its progress, there existed one vital fault in the shaft that confined its use to light power machines. If, in any of the forms heretofore described, the length be over a certain number of diameters, its power-transmitting capacity becomes extremely limited on account of its liability to kink or twist out of line and double up into twisted loops. The effect is easily seen by taking a short piece of rope, fastening one end and twisting the other. The rigidity of the rope will be found to increase to a certain limit, when at some point it will suddenly twist into a loop. Shafts of this form, also, if run at a speed of more than three or four hundred revolutions per minute, vibrate in a very curious manner, the shaft divid-

* Thos. Welham, Jan. 31, 1865. Improvement in Universal Shafting.

† Greene V. Black. Patent of Aug. 8, 1871. Improvement in Universal Joints for Shaft Couplings. The title of this patent indicates the restricted use of the principle at that time.

ing into equidistant nodes like the strings of a musical instrument. This action is usually so marked as to interfere with the proper functions of the working tool, giving it a tremulous motion that is difficult or impossible to control. These defects were finally overcome by enclosing the revolving shaft in a flexible *stationary* sheath or case, and at the same time the carrying power of the shaft itself was increased by making it solid all the way through, in the sense that a wire rope is solid.* The effect of the case or sheath (a hollow coil of wire covered with leather or other flexible material) was to give the revolving core an indefinite number of bearings, in whatever direction it might be placed, thus entirely preventing the tendencies of the naked core to kink and vibrate as described above.

FIG. 1.



Upon reflection it will be seen that this is simply an extension of

* Nelson Stow. Patent of Aug. 6, 1872. Improvement in Flexible Shafts.

the principle we employ with rigid shafting that is too light to carry its load without vibration; we *increase the number of bearings*, and thus break the shaft into shorter sections. The increased metal section of the "solid" shaft, while enhancing its strength, of course again diminished the flexibility. Since, however, the action of the case permitted the use of much longer shafts than were practicable without it, this loss of flexibility was of comparatively small importance, as the same amount of total curvature could be obtained by making the curve more gradual and increasing its length.

Thus, a shaft $\frac{3}{8}$ in. diam. (of core), and six feet long, will work in a complete circle or total angle of 360 degrees.

*As now constructed the flexible shaft is made up of a *core*, a *case*, and appropriate fittings by which the two are joined, and rotary motion communicated to one end of the shaft and delivered at the other. These parts are shown, partly in section, in the annexed cut.

The core is composed of a series of concentric steel wire coils wound hard on each other, the direction of the pitch changing with each layer. The pitch direction of the outside layer is always such that the latter will tend to contract under strain, the shaft always running one way. The case is made of a hollow coil of square wire, with a slight groove on the outer side. This coil is covered with leather, the office of the groove in the wire being to prevent the leather from slipping. The inside diameter of the case is slightly larger than that of the core, and the ends are furnished with iron ferrules to receive the driving pulley and the hand-piece carrying the working tool.

The mechanical action of the shaft may best be analyzed as follows: Imagine two concentric coils of wire bent in a curve as in Fig. 2. On the outer curve the helices are spread or open, while on the inner curve they are in contact or nearly so. Now suppose the coils to be bent in the opposite direction, as in Fig. 3. The parts that were formerly in contact are now separated, and *vice versa*. This change of curvature from the position of Fig. 2 to that of Fig. 3, and back again to that of Fig. 2, is precisely in effect what occurs in the shaft during one entire revolution, except that each successive point on a given helix occupies the top and bottom positions respectively, instead of only two meridian points, as when the coil is simply bent back and forth. At every moment, then, some point in every helix is undergoing a slight

* The Stow Flexible Shaft Co., Limited, 500 N. 15th st., Philadelphia, are the sole makers of the flexible shaft for other than dental purposes.

torsion, whose amount depends upon the diameter of the particular coil in which it is situated, and the curvature of the shaft itself. As long as this torsional strain is kept within the limit of elasticity of the material the shaft will revolve indefinitely without detriment; but should this limit be exceeded the shaft will rapidly give way. If a piece of core be mounted in bearings, and *curved excessively*, it will

FIG. 2.

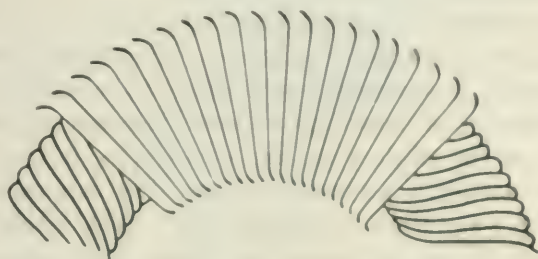


FIG. 3.



soon begin to heat, if set in motion, and will finally break. In practice this contingency is provided for by making the case sufficiently rigid to prevent bending beyond the safe limit. Referring again to Figs. 2 and 3, it will be seen that there must be some slight rubbing action between the wires of the inner and outer coils. The effect of this action is so slight as to be imperceptible, even in shafts that have been a long time in service. The other frictional elements are those common to all machines, viz., the wear of the journals and their bearings, and the wear of the outer layer of the core at points of contact with the case.

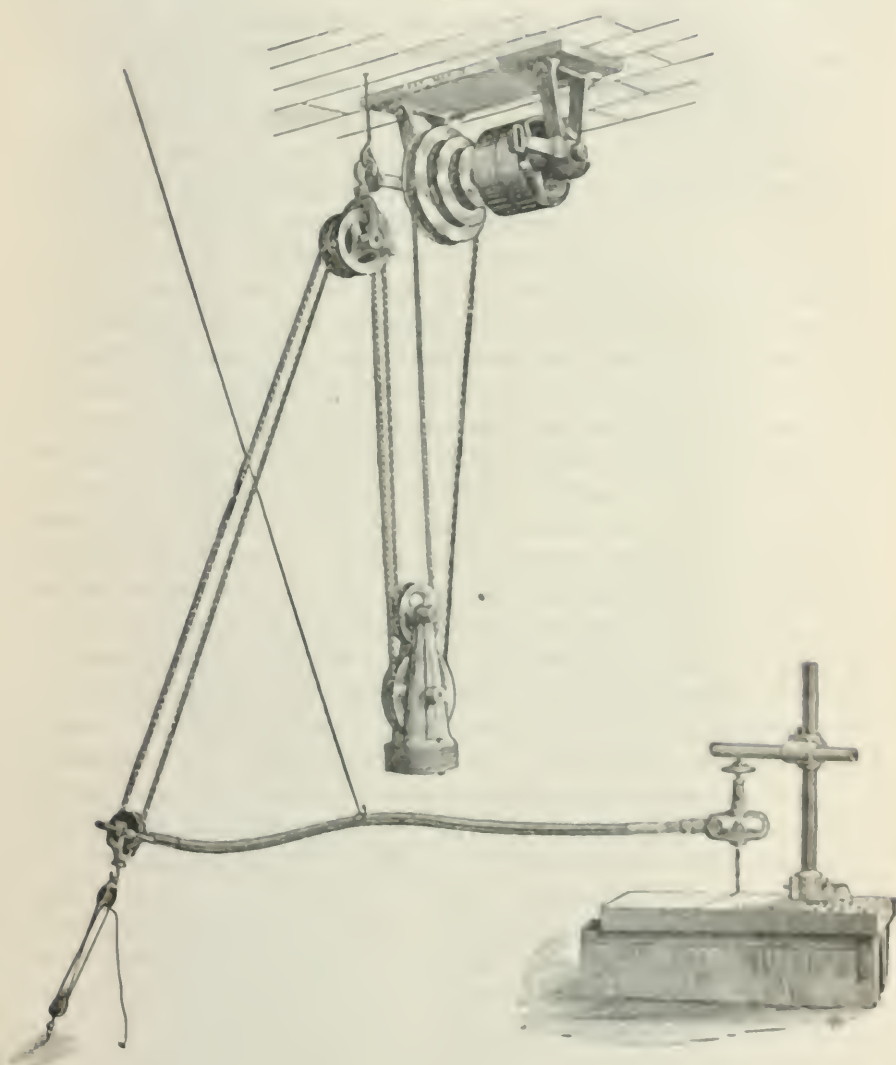
Since the flexible shaft is not a special tool for a particular purpose, but a connecting link between a given power source and a multitude of tools, its uses are very varied. The first successful application of this

tool was in dentistry, the necessities of the dentist being, in fact, its *raison d'être*. It is needless here to descant upon its use in this line, however, as nearly every one who has need of the dentist's services is familiar with the dental engine and its power of shortening the time of painful operations on the teeth. In heavier operations the leading place occupied by the shaft has been in metal drilling. The usual power drills are no exception to the general rule stated above of *fixity in certain planes of motion*.*

Even the radial drill only means the ability to drill *vertically* in a cylindrical space a few feet in diameter. Hence the power drill still puts the burden of adjustment on the piece to be worked itself, while the inconvenience of handling the work increases very rapidly with the weight and size of the piece, and soon reaches, in the case of large boilers, for example, a prohibitive limit. For this reason, in every machine shop many holes are still drilled by hand, within sight of the engine, that is willing but powerless to assist. It was soon seen that the flexible shaft would prove a valuable adjunct in such cases, and appropriate tools were made to meet the requirements. Extension is obtained, not by increasing the length of the shaft, which is seldom over eight feet in length, but by increasing the length of the driving rope. Varying directions are obtained; first, by leading the rope through a "transfer pulley," which is simply a pair of idler pulleys mounted one over the other in a light frame, and attached to the floor directly under the counter-shaft. Second, and more conveniently, by a device styled a "roundabout transfer," consisting, first, of a pair of idler pulleys, mounted one over the other in a weighted frame, and, second, of a pair of pulleys in a swivel frame, attached to a hanger adjoining the countershaft. The driving ropes lead from the counter-shaft down to the weighted frame, then over the swivel pulleys, and thence to the pulley on the flexible shaft, as shown in the accompanying cut. With this device the shaft and its drill may be carried at will to any part of the shop, the only limits being the length of rope used and the height of rise and fall at command for the weighted frame. Since both the leading and following ropes are carried down to the weighted frame, and thence over the swivel pulleys, the combinations form in effect a system of one *fixed* and one *movable* pulley; hence

* A notable exception to this is the Thorne Portable Drill, described in the JOURNAL of November, 1871.

Fig. 1





the available extension of the drill is *twice* the rise of the weighted frame, an attribute of considerable importance in low-studded rooms.

The shaft is also used for grinding and polishing metal work with emery wheels, wood, walrus hide and felt wheels, coated with emery, etc. Attachments are provided by which the wheel may be used either on edge or on the flat side. In solid wheels the limit to the size that can be used on edge is soon reached, as the reaction of a wheel greater than six inches in diameter, running at the necessarily high speed, is so great that it cannot be held to the work. With smaller wheels this difficulty is not encountered, nor does it occur with soft wheels. In polishing bright work, as show-case frames, etc., the familiar rag-wheel is used with rouge or other polishing powders.

One of the earliest suggested uses of this tool was cleaning the sand from castings with wire brushes. In the effort to carry out this idea, existing methods were naturally followed, and circular brushes were made filled with flat steel wire bristles, after the usual manner. It was soon found, however, that what answered well enough under the slow, reciprocating motion of the hand, was an utter failure under the rapid, circular motion of the shaft, a large percentage of the wires breaking in a few hours' use. This result was probably due to the molecular changes induced by the rapid vibration of the wires. Various kinds of wire were tried and numerous methods of "packing" with rubber and other elastic materials, but without avail, and the idea was temporarily abandoned. Recently, however, a brush, acting upon an entirely new principle, has been invented, and seems to answer all the requirements. Two thin iron disks, about four inches in diameter, are mounted on a threaded spindle, one end of which is attached to the flexible shaft. These disks are placed about two and one-half inches apart, and are connected by a series of small rods placed at intervals around the circumference. The "hub" thus prepared is not unlike a small squirrel cage in appearance. Upon these rods short wire links are loosely hung, and from the links depend wires of ordinary round steel, about three inches long. We have thus a brush whose bristles are held to the backing by a free joint instead of the usual rigid connection. When stationary the wires hang perfectly limp, but when in motion, at the proper speed, the centrifugal force keeps them normal to the axis until the surface to be cleaned is reached, when they yield and drag across it. It is found in practice that the brush so constructed is as efficient as the stiff brush, and is much more pliable, adapting

itself better to irregularities in the surface, while the wear is entirely confined to the joints and gradual abrasion of the ends of the wires. Wheels for sand-papering wood work, made upon the same principle, have been tried and found very effective. The sand-paper is cut into circular disks, which are strung on an appropriate mandril, each disk being separated from its neighbor by a small washer. This arrangement gives the tool great flexibility and at the same time does away with the inconvenience of frequently renewing the cutting surface inherent in the plan of wooden centres covered with sand-paper, since it is effective until worn nearly to the centre.

The shaft has also been found of great utility in stone working operations. The horizontal "lap" that has so greatly expedited the surfacing of small pieces is of no avail for large blocks, on account of their great weight and size; but the shaft enables the lap, on a small scale, to be carried to the work itself. In the apparatus constructed for this purpose, either turned iron disks or frames carrying concentric rings made of zinc, are attached to geared machines (similar to the drill press) on the end of the shaft. The grinding material is sand or emery with water.

The following tables give the results of a series of tests and experiments made in August, 1877. Recent improvements in the make up of the shaft would doubtless change these figures somewhat.

TABLE NO. 1.

1	2	3	4	5
Selling No. of Shaft.	Length of Specimen.	Diam. of Specimen.	Proof Strain in lbs. at 1 foot from centre.	Angle at Elastic Limit.
0	3	9.32	4.018	77.
2	3	3.8	9.715	30.3
3	3	1.2	21.109	20.6
4	3	5.8	41.346	29.
6	3	15.16	119.832	10.7

The figures in Table No. 1 are from a series of actual tests made at the Stevens Institute of Technology, Hoboken, N. J.

By Proof Strain is meant the maximum weight which the specimen carried (at a distance of one foot from the centre), without giving the material a permanent set.

The tests in Table No. 2 were made with an Emerson Dynamometer.

TABLE NO. 2.

1	2	3	4	5	6
No. of Test.	Rolling No.	Speed of Shaft.	NATURE OF WORK.	Work done ft. lbs.	REMARKS.
1	4	1300	$\frac{1}{2}$ in. Aug. in Pine	36288	Shaft nearly straight.
2	"	"	" "	36288	" bent through $\frac{1}{2}$ circle.
3	"	1050	$\frac{3}{8}$ in. Augur.	34992	" " " $\frac{3}{4}$ "
4	"	"	" "	36288	" " " $1\frac{1}{4}$ "
5	"	700	1 in. Augur.	41472	" nearly straight.
6	"	"	$\frac{3}{4}$ in. drill in cast iron.	33048	Drilled $1\frac{1}{2}$ in. in 2 minutes.
7	"	"	$\frac{1}{2}$ in. Drill.	34992	" $1\frac{1}{2}$ in. in 1 "
8	"	"	$\frac{3}{8}$ in. Drill.	40176	" $\frac{1}{2}$ in. in 1 "
9	6	412	Not Working.	6400	New Shaft. Straight.
10	"	"	$\frac{3}{4}$ in. drill in cast iron.	20480	Drilled 2 in. in $1\frac{1}{2}$ minutes.
11	"	"	1 in. " "	23680	" 1 in. in 1 "
12	"	"	$1\frac{1}{4}$ in. " "	26240	" 1 in. in 1 "
13	"	950	Friction Wheel.	69552	No injurious effect on shaft.

Besides those mentioned above, the shaft has been utilized in many minor operations, as horse and cattle brushing, plate glass cleansing and polishing, morocco finishing, and even in *boot-black*ing. From its position as an intermediate term or connecting link between the working tool and the power source, leading mechanical power into the more intricate ways and remote corners heretofore only approachable by the human arm, it is apparent that manifold applications of the flexible shaft will be made in the future that are not now considered.

ACCIDENTS IN THE COMSTOCK MINES AND THEIR
RELATION TO DEEP MINING.

By JOHN A. CHURCH, M.E.

A paper read at the Pittsburgh meeting of the American Institute of Mining Engineers, May, 1879.

Early in the month of August, 1877, a miner in Gold Hill, Nevada, made the unlucky remark that, according to his observation, that month was usually quite free from accidents in the mines. Never was presage wider from the truth. When the month closed twelve mishaps had occurred, killing six and wounding nine persons, and for the rest of that year the Comstock mining communities were kept in a ferment by the frequent occurrence of appalling disasters. There was a real tidal wave of calamity sweeping over the mines, which has not been repeated since, and according to common report was never known before on the Comstock. I was much interested in studying the character of these misfortunes, which also aroused concerted action on the part of the miners, and I have collected a list of the accidents which took place from July, 1877, to May, 1879. The number in this period of twenty-two months is 101, killing immediately 53 persons and wounding 70 others. This list is incomplete in every way. All accidents which did not injure persons are omitted, and there are several which were of a threatening kind but fortunately did no damage to human beings. Probably others have been overlooked which did belong to the category included in my lists. Finally, no effort has been made to ascertain how many of the wounded died of their wounds, and the number of fatal casualties includes only those who died so soon after their injury that their death became a part of the current records of the accident.

Many of these accidents belong to the usual classes of mishaps in mines and will receive no extended discussion. Others are worth examination from their connection with labor in hot mines, deep mining, and other causes intimately dependent on the local conditions of the Comstock. They may all be classified under eight general heads: 1. Falls of rock, timber, etc. 2. Trammings. 3. Effects of heat. 4. Falls of men. 5. Explosions. 6. Hoisting apparatus. 7. Over-

winding. 8. Miscellaneous. The distribution among these groups in each year is shown in the following summary :

	1877 6 mos.	1878	1879 4 mos.
(1.) Casualties due to falls of rock, ice, timber, etc.			
Number of occurrences, ...	8	7	8
Casualties, fatal, ...	2	4	3
Casualties, not fatal, ...	7	4	5
Proportion fatal, 36 per cent.			
(2.) Casualties in tramming.			
Number of occurrences, ...	4	3	
Casualties, fatal, ...	1	0	
Casualties, not fatal, ...	4	3	
Proportion fatal, 12½ per cent.			
(3.) Casualties due to heat.			
<i>Scalding :</i>			
Number of occurrences, ...	1	2	
Casualties, fatal, ...	1	1	
Casualties, not fatal, ...		1	
Proportion fatal, 33 per cent.			
<i>Overheating :</i>			
Number of occurrences, ...	1	8	
Casualties, fatal, ...	1	7	
Casualties, not fatal, ...		3	
Proportion fatal, 73 per cent.			
(4.) Casualties due to falls of men.			
Number of occurrences, ...	7	7	2
Casualties, fatal, ...	2	6	2
Casualties, not fatal, ...	5	1	
Proportion fatal, 62½ per cent.			
(5.) Casualties due to explosions.			
Number of occurrences, ...	5	6	3
Casualties, fatal, ...	3	2	5
Casualties, not fatal, ...	5	6	
Proportion fatal, 71 per cent.			
(6.) Casualties in hoisting.			
Number of occurrences, ...	4	6	1
Casualties, fatal, ...	2	3	1
Casualties, not fatal, ...	2	6	
Proportion fatal, 43 per cent.			

	1877 6 mos.	1878	1879 4 mos.
(7.) Casualties by overwinding.			
Number of occurrences,	1	2	
Casualties, fatal,	1	2	
Casualties, not fatal,	1	1	
Proportion fatal, 60 per cent.			
(8.) Casualties due to miscellaneous causes.			
Number of occurrences,	7	8	
Casualties, fatal,	1	3	
Casualties, not fatal,	10	6	
Proportion fatal, 20 per cent.			
Total occurrences,	38	49	14
Total fatal casualties,	14	28	11
Total casualties not fatal,	34	31	5
Grand total for 22 months:			
Occurrences,	101		
Total casualties,	53		
Casualties, not fatal,	70		
Proportion fatal, 43 per cent.			

This list is not offered as a summary of accidents in the Comstock mines, but merely as an index to the causes which operate there to endanger life. Many of these are common to all mining operations, but others are quite peculiar and deserve timely discussion, for it is supposed that they are likely to increase in force with the deepening of the mines, which is now rapidly progressing.

In the third class, or those casualties which are due to the high temperature of the mines and the rock in which they are opened, we have some of the most singular occurrences known in mining. The injuries by scalding were occasioned entirely by falling into the hot mine waters. Their temperature varies with the locality, but the maximum which I have observed is 156° Fahr., and usually it is considerably below this. This temperature seems to be sufficient to produce serious effects. One miner, who slipped into the Julia water, sinking nearly to his knees, got out so quickly that the water did not have time to enter his shoes, and yet his legs were scalded so severely that the skin came off. The same mine was flooded early in the present year with water which was reported to have a temperature of 158° Fahr., and a miner who, in a fit of absent-mindedness, stepped into it, immersing

himself to the chin, was fatally injured. The water is hot and gaseous, and the unfortunate man who falls in it sinks deeply and probably finds it difficult to regain the surface.

But it is in the effects of work in hot air upon the human frame that the most remarkable casualties are witnessed, and this class is purposely put first among those which are to be discussed, because it seems probable that a considerable proportion of all kinds of accidents in these mines are indirectly due to the heat. The proportion of fatal casualties is larger in this class than in any other, being 73 per cent., and from the peculiar mental effects of the heat it is obvious that it may be and probably is the initiating cause of many mishaps which would under other circumstances be ascribed to culpable blundering.

On the 1900 level of the Gould and Curry mine a drift was run to the southward from the shaft, following the line of the black dyke and lying quite near it. This proved to be one of those hot spots which I have before described to the Institute as a marked peculiarity of the Comstock rocks. As a rule the drifts at this depth have not been above 108° or 110° , and many have been less hot, but this drift has several times been reported to show a temperature of 123° , 126° , and 128° Fahr. Thomas Brown, a miner working in this place, fainted, and when taken to the surface and revived, was found to have completely lost his memory. He could not tell his name or where he lived, and had to be dressed and taken home by his friends. The paper which records the occurrence says: "This sudden loss of memory from overheating is quite common in the mines, but the effect soon disappears and the men are themselves again. This fact furnishes an explanation of how men, who are considered experienced miners, walk off into fatal winzes and chutes, seemingly with deliberate intention."

A frequent accident in these mines is fainting in the shaft while the cage is rising to the surface. The faintness is always felt immediately upon reaching the cooler air a hundred or a hundred and fifty feet from the surface, where there is usually a side draft through some adit. This casualty is so common that a man who has been working in a hot drift is not allowed to go up alone. Long habitude to the heat is no safeguard against this danger, and serious accidents have occurred in this way. The faintness, I believe, is preceded by nausea, but insensibility follows quite suddenly.

Among the minor casualties I have included one which is said to have happened to Mr. Sutro. Being in the Sutro tunnel before it made

connection with the Savage mine, and in an air temperature of 110° Fahr., he went to the air pipe to cool off, and staid there so long that the miners told him to get away from the pipe and let them have air. He did not move, and the account says they tried to stir him up with the handles of their shovels, but he had lost all volition and could not budge. Finally he was put on a car and taken out.

These are the minor effects of the heat. Its graver results are well shown in the following cases of insanity and death :

The first of these, which I introduce with some hesitation, is described by the *Virginia Evening Chronicle* as follows: "At half past nine o'clock Monday morning, March 11th, 1878, a man died at the Caledonia mine in Gold Hill, under peculiar circumstances. The man had been iddle for six months, and was working his first shift in that time, he having gone down this morning at seven o'clock. He was put to work as carman on the 1400 level. At the hour stated he rushed into the station at the 1400 level and told the station-tender that the wheels of his car were smashed all to pieces. The station-tender walked back with him to the car, when it was found all right. The station-tender thereupon saw that something was wrong with the man, and took him to the cooling-off place. There he soon began talking wildly and behaving boisterously, and giving other indications of mental aberration. It was therefore thought best to bring him to the surface. He was firmly lashed to the cage and hoisted up, but on reaching the surface he fainted away and died in a few minutes."

The heat on the 1400 level of the Caledonia is not very great, being about 90° Fahr., and this man's sudden decease may have been due to other causes.

Of the other fatal casualties, one was from cramps, which the account attributes to the heat, but which may have been the result of drinking ice water, and another was from a cold taken while cooling off after being partially overcome by the heat. It is to the drinking of ice water and the comfort of a strong draft that the men resort for recovery from the exhaustion caused by the heat, and though these methods, so contrary to the ordinary rules of hygiene, are put in use several thousand times a day, and usually with impunity, these two instances are proofs that they may be dangerous. The miners consider the draft of cool air safer than drinking copiously of ice water, but when in the mines I choose the latter method to save time, and never felt ill effects from it.

The next case illustrates the violent effects which excessive heat may have upon a person not accustomed to it: "On Friday, October 11th, 1878, John McCauley went to work for the first time in the Imperial mine. He was cautioned against over-exerting himself in the extreme heat of the lower levels. He replied that he thought he was strong enough to stand anything and paid no attention to the advice. At half-past two in the afternoon he was brought to the surface in an unconscious state, and died the next morning at half-past ten o'clock."

Two other cases very similar to this have occurred in the Imperial within a few years. This mine is excavated in one of the hot spots of the Comstock.

The hot drift on the 1900 level of the Gould and Curry is the scene of the most serious of these casualties due to heat. Five men were sent there in June, 1878, to load a donkey pump on a car. The work was so exhausting that when the pump caught on a plank they were not able to move it. They seem to have been in a state of mental confusion, but felt that they could not remain longer. Starting up a winze which connects with the 1700 level one man fell on the way, and the others were afraid to stop to help him, but pressed on, reaching the 1700 in half an hour from the time they left it. They were very confused and nearly speechless, and hardly realized what had occurred. Three men went down to the rescue and found the fallen man still alive. Clearing the pump they got into the car and signalled to hoist, but on the way up the winze the man they had gone to rescue recoiled and fell off. The car was stopped at once, but he was jammed between it and the brattice so fast that the others left him and went for help. They all gave out, two half way up, and the other just as he reached the 1700 level, where a friendly hand pulled him up. A new rescue party went down and found two men dead, and the third died soon after. The shift boss reports that "the accident was due solely to the heat, as the air is good enough and pure enough, barring the heat." The winze was not an abandoned one, but in daily use. A heavy volume of steam is reported to rise through it from the 1900 level, the temperature of which, at the time of this accident, is given at 128° Fahr. I gather from the detailed account that the death of the men is possibly attributable to the fact that when the miner fell off the car the latter was stopped in a place that was hotter than the rest of the winze.

It is to be regretted that no adequate studies have been made upon

the precise physiological phenomena presented by death under these circumstances. The legal requirements are satisfied when it is proved that the casualty was due to "heat," but if the theory of heat production in these rocks, which I have advocated before you, is correct, and currents of hot gas, rich in carbonic acid, are pouring through narrow belts of shattered rock, the death of men who are stopped in one of these belts may have a more complex cause.

(4.) The most appalling accident which can occur in mining work, the falling of men down a deep shaft, repeats itself in the Comstock mines with a frequency which, I believe, is unknown elsewhere. Sixteen occurrences of this kind took place in twenty-two months, and ten of the casualties were fatal. There were seven falls in the shaft, six in winzes and one in a chute, and three in the floors. One of these deaths was traceable to the effects of foul air, the lights having gone out and the party being on the cage in retreat from the drift.

These dreadful accidents being more common on the Comstock than in any other mines that I know of, it is important to ascertain whether this frequency is attributable to the heat. In some cases we may answer in the affirmative. When a timberman repairing the upcast shaft of an unusually hot mine falls to the bottom we may fairly conclude that the tendency of blood to the head which the lifting of a heavy weight occasions may have been increased to momentary stupefaction by the heat, steam and gases of the shaft. But though my own impression before examining this subject was that the heat was largely accountable for these mishaps, I am forced, by a study of the casualties in this record, to admit that this is not the most frequent cause of them. If the Comstock miner is more liable than his fellows to this form of accident, it is because he is more often called to work in the shafts after they have been completed.

The Comstock shafts are all sunk in the hanging wall, and the vast excavations which have been made in most of the mines make the settling of this wall inevitable. But besides that, the Comstock rocks are forever moving, swelling and forcing the shafts out of line. No shaft there is in perfectly good condition. Some stand remarkably well, and keep in working order for years, while others require frequent repairs; but from the day they are completed their deterioration is steady, until a general overhauling is necessary. They are timbered in a manner which allows remarkable variation from their original alignment without loss of local support to the ground, and this timber-

ing is rapidly and conveniently readjusted when pushed too far out of line. The work of repair is necessarily dangerous and more hazardous in a hot steaming upcast shaft than in a cool one, and it is to the frequency with which the Comstock miner is called upon to perform this work that the number of falls in the shaft is to be attributed. It is also undeniable that the unfavorable heat conditions may contribute essentially to the result, but of the two causes I consider that frequent opportunity is the greater.

But the falling of timbermen is not the only mode in which this accident occurs. Another is the product of pure forgetfulness. A man working near the shaft will sometimes step off upon vacancy and meet his death. The movement is made quietly—not in the heat of action, but after the completion of some task—and above ground such actions are attributed to “absent-mindedness.” I think this state of inactive perception is exceptionally frequent among Comstock miners, and it stands in such strong contrast to the habits of forethoughtfulness to which they train themselves that we must attribute it to the effect of physical exertion in hot air.

Another class of falls in the shaft are partly due to the high professional spirit and sense of individual responsibility, which makes the Western miner one of the most trustworthy of his class. This mode of occurrence, which is unexpectedly frequent, is the pushing of a car into a shaft where there is no cage. This is sometimes due to pure absent-mindedness, and sometimes to an interruption of the routine work by a cage going up empty, with a message, with tools or with a passenger. It is said to be a fact that when a carman has pushed his car to the open shaft and has suddenly awakened to the dreadful situation, he never fails to sacrifice his own life in efforts, however hopeless, to stop it. Whenever a car thunders down the shaft, there is always a man with it, and whenever the circumstances have come under observation, it has been evident that the loss of life was not due to stupefaction but to a dogged determination to stake everything on the hope of preventing a possible calamity to men below. The spirit is well illustrated by the act of a man who fell down a shaft at Bodie, and used his last breath in calling out “Look out below!” Though this casualty appears so frightful to those who witness it, it is probably as painless as other modes of certain instantaneous death. I have been told that the unfortunate men always lose their shoes in their fall, and

also that they invariably reach the bottom sooner than the car, if one falls with the man.

(5.) The history of blast accidents in the Comstock mines enforces the truth that the nitroglycerine explosives do not enjoy the immunity from ignition by friction which has been asserted for them so confidently. We have to admit that a box of cartridges can be thrown off a house with safety, for that has frequently been done, but inclosed in a drill-hole they have been fired repeatedly by friction, jarring or a blow. Out of fourteen accidents five occurred from the explosion of unsuspected cartridges by one of these causes.

Two cases of wounding are peculiar from the fact that the exploding cartridges had been in the rock a long time. Each of them lay, not in the header, but in the floor of a drift or chamber, and the accident occurred when orders were given to level up the floor. The explosions were in different mines, and one of the miners was using a pick, the other a gad. Neither was killed.

Two men were wounded by the explosion of a cartridge which they were drilling out for repriming. Three accidents occurred from the explosion of old cartridges left in the header, the presence of which was not suspected, and which were fired, not by direct impact of the tool, but by the jar or the crowding in of the rock upon the cartridge owing to the starting of a new drill-hole near by. Two of these were caused by machine drills, and one by hand drilling. It is supposed that in some cases at least the exploding cartridge was not a complete one but merely a fragment, the upper portion having done its work. This seems probable, for instance, in the cases of the two men who were injured while levelling off the floor, for it is hardly conceivable that a full cartridge could blow up the floor beneath a man's feet and leave him alive.

One of the explosions took place under peculiar circumstances, which exhibit very well the sensensitiveness of nitroglycerine to the conditions in which it is placed. A hole having missed fire, the next shift opened and recharged it. After lighting the fuse the men waited the usual time, and one of them then went to the face and found the cartridge was "boiling," making what miners call a "stinker." It was concluded to drown the hole out, and a man took up water from the wet floor in his shovel and threw it on the boiling cartridge. While stooping for another shovelful, the half-burnt charge exploded. The superintend-

ent, Mr. Forman, who was present, attributes the explosion to the confinement of gas by the water, and the suggestion is a sensible one.

(6.) Hoisting on the Comstock has peculiar dangers from the movement of ground in the shafts already spoken of. It is often impossible to keep the guides in anything approaching a straight line. The shove is not only considerable, but it is frequently confined to short reaches in the shaft, and this displacement of line is the cause of frequent dangers and sometimes of serious casualties. The cage sways from side to side, with motion sufficient to make it absolutely necessary to hold firmly to a rod placed in the top for the purpose. Among the casualties of 1877 was one caused by the violent surging of the cage in the Consolidated Virginia shaft, by which a miner was thrown off his balance, one foot going over the side. He escaped with a sprained ankle. Sticking of the cage during its descent and its subsequent fall with a jerk, is one of the most frequent causes of these accidents, and the cage sometimes also gives a sudden bound when rising.

(7.) Though overwinding is neither the most frequent source of casualties nor the most fatal in its results, it has aroused more attention than any other. In twenty-two months, cages containing men were twice "run into the sheaves," as the local expression is, and I have notes of four others where no men were hoisted, but one of which proved injurious to persons. Two of the fatal cases occurred at the same mine within five and a half months, and the other, which was caused by overwinding a heavy bailing tank, followed soon after. These, and the running of several empty or ore-laden cages into the sheaves, made a great excitement, and the Society of Engineers tried to prove that the men at the engines were overworked. They formerly worked twelve hours at many shafts, and on solicitation were reduced to eight hours at some. The pay for twelve hours' work was usually \$6, and for eight hours \$4.50 or \$5.

One result of the excitement occasioned by these dreadful casualties was the introduction of several safety devices. Nothing new was presented, there being detaching devices which depended on safety catches for supporting the cage when connection with the cable was severed, others with especial chairs to detain the cage, and one with a rope wound on a false reel to support the cable and carry it quietly to the hoisting drum or reel. In addition the usual appliances for throttling the exhaust from the cylinders of the hoisting engine, shutting off steam gradually and putting on the brake have been re-invented.

The gallows frames at most of the old shafts are thirty-five feet high, and with a "double-decker" cage that takes up twelve or fourteen feet of this space, it is evident the engineer has but a small margin for safety. The new shafts have frames forty-five feet high. It seems to me that the disinclination to use preventive appliances should be overcome. The tendency on the Comstock is to employ unbalanced reels, and with these, mere bleeding of the steam pipe should be sufficient to prevent serious injury. With balanced reels it would be absolutely necessary to put on the brake also.

(8.) One of the accidents classed among the miscellaneous causes is worthy of attention. Several years ago an electric signaling apparatus was introduced into the Savage mine, but abandoned on account of the uncertainty of its signals, which would sometimes sound without human aid. In 1877 a new apparatus was put in with improvements, which it was thought would prevent this disadvantage, but after working well for some time, it failed one morning and caused a fatal casualty by sounding only three bells, when ten were intended. Whether the signal man was at fault is doubtful, but it is a fact that the apparatus had worked badly that morning, and before the accident a man had been stationed to signal with the bell-rope in case the battery did not work. There is little confidence in the electric mode of signaling, and, I believe, it is not in use now in any mine on the lode. A small wire-hand-rope is used, and on the whole is safe and convenient.

In looking over this list of casualties it is evident that the accidents which possess most interest are those which have near or remote connection with the heat of the mines, for the latter are sinking with great rapidity, and becoming hotter each year. During the past eighteen months they have been deepened four hundred to six hundred feet, and it is difficult to deny that the greater depth increases the chances of accident in mines which, in addition to the ordinary liabilities of mining work, have the insidious and ever present effects of hot air, water and rock upon the physical and mental condition of the men. While I have never myself doubted the ability of the excellent managers to carry the works in these hot rocks down to the greatest depths that are anticipated for mining in any region, I find there is widespread doubt in the West upon this subject. There is an impression that the Comstock lode has nearly reached the end of the mining rope, and the reason usually given is that life cannot be sustained in the great heat of the lowest workings, which heat the popular mind loves

to exaggerate. The record I present in this paper should be sufficient to dispel such doubts. Out of 101 accidents twelve were directly caused by the heat or hot water. Undoubtedly the falls of men down a shaft have been caused sometimes by sudden exhaustion, due to the heat and steam in upcast shafts, but on looking over the accounts of the accidents of this kind, which are included in the above list, I cannot find any of them that show a connection with this cause. The casualties positively traceable to the heat are, therefore, twelve per cent. of the whole. Probably the heat increases the bad effects of powder fumes and natural gases, and by making repairs to the shafts more frequently necessary it adds indirectly to the occasions when disasters may occur. I also confess to the belief, which is not sustained by observations upon specific casualties, that some allowance should be made for a less active mental condition, a dulling of the faculties, and a certain recklessness to which the heat sometimes goads the men. On the other hand the heat makes them more cautious except when under momentary impulses, and I have never seen American miners more careful of themselves than in these mines. On the whole, the good and bad effects of the heat seem to nearly balance each other, and I think that an allowance of five per cent. for the casualties indirectly caused by the high heat would be sufficient. The specific cases which I present do not warrant even that allowance. The accidents recorded here relate to a time when the number of miners at work in the district was from three thousand to thirty-five hundred, including top men and underground men. Most of them worked eight hours, but some of those on top had twelve hour shifts, and probably there was a constant force of nine hundred or one thousand men below.

It is not possible to make a comparison between these casualties and the amount of ore raised, as the practice is in statistics of coal mines, for the reason that only two out of about forty mines were producing much ore throughout the period covered by the list. The comparison can be made for those two, the Consolidated Virginia and California, and is as follows for the year 1878 :

		Proportion to tons ore
Number of accidents, 10,	.	1 to 25,771
Fatal casualties, 5,	.	1 to 51,542
Casualties not fatal, 8,	.	1 to 32,214
Tons of ore extracted, 257,718.		

Of the casualties included in the list for twenty-two months there

were in these two mines twenty-five accidents, twelve fatal, and eighteen not fatal casualties, or twenty-five, twenty-two and a half, and twenty-six per cent. of the whole.

From all these facts I conclude that increasing heat will not debar the Comstock mines from continuing to the greatest depths which are considered practicable in the existing adjustment of mining appliances to the market value of mining products. It is true that an air temperature of 108° Fahr. is common at the 2000 feet level, while 110° and 112° are not infrequently observed, and that a drift which showed a temperature of 123° , 126° and 128° Fahr., according to different reports, has proved to be the most deadly on the lode. It is also true that the temperature of the rock is increasing, and with it that of the air, and at some depth, for the calculation of which there are absolutely no data, the temperature of this drift may be expected to prevail throughout the lode unless the present conditions change. But this being an *air* temperature, it is always possible to mitigate it by artificial means. It is already observable that drifts 1800 feet below the surface may show a much higher heat than others 400 feet below them. High temperature is largely a matter of locality and temporary conditions, and by various expedients it may be confined to its localities, or combated in other ways.

Deep mining, by extending the line of work through the moving hanging wall, and compelling increased repairs to shafts, will perhaps tend to heighten the already great frequency of falls of men.

In addition to the heat, the peculiar mode of timbering in square sets, the almost exclusive use of nitroglycerine powders, the necessity of frequent repairs to shaft timbers, the incessant movement of the rocks through which the shafts are sunk, making accidents in hoisting more than ordinarily frequent, and the necessity of transporting large quantities of rock through narrow gangways entirely by human labor, are the conditions in which mining on the Comstock may be said to suffer rather more than the usual liability to danger. Two of these causes, both connected with the movement of the ground, may be expected to increase with depth. Together with the heat they comprise forty per cent. of the whole number of accidents, and we may therefore sum up our conclusions by saying that the conditions of deep mining will increase forty per cent. of the causes which lead to casualties, and will leave sixty per cent. unaffected. What the amount of this increase will be cannot be foretold, and indeed cannot be estimated until an ore body

has been found and worked at great depth. So far the year 1879, which is pre-eminently one of deep sinking on the Comstock, has been remarkably free from casualties.

The administration of the mines is excellent, and the oversight ample. Though there is no declared law, I observed that an accident was likely to be followed by the discharge of some miners, and several times the sufferers went before a magistrate and made oath that they were not only entirely innocent of negligence, but absolutely ignorant that there was any danger impending, or that there was any one near who could be injured if an accident should take place. The managers seem to have come to the conclusion, which guides the framers of some European mining laws, that accidents will not cease until the damage is assessed on every one in the neighborhood of the casualty, innocent or guilty. The Miners' Union is an active and powerful body, and does not hesitate to express an opinion on the conduct of the mines.

The Compass.—The secret of the steadiness of a large compass is the longness of its vibrational period, and a small card would have the same steadiness as a large one if its vibrational period were the same. How little this is known is illustrated by the methods of procuring steadiness in common use. In some (as in the Admiralty "J" card, provided for use in stormy weather) there is a swelling in the middle of each of the steel needles to make them heavier; in others heavy brass weights are attached to the compass cards as near the centre as may be, being sometimes, for instance, in the form of a small brass ring of about an inch and a half in diameter. Another method, scarcely less scientific, is to blunt the bearing-point by grinding it or striking it with a hammer, as has not unfrequently been done to render the compass "less lively," or to fill the cup with brick-dust, as is reported by the Liverpool Compass Committee to have been once done at sea by a captain who was surprised to find afterwards that his compass could not be trusted within a couple of points. All these methods are founded on the idea that friction on the bearing-point is the cure for unsteadiness. In reality friction introduces a peculiar unsteadiness of a very serious kind, and is very ineffectual in remedying the proper unsteadiness of which something is essential and inevitable in a compass on board a ship rolling in a heavy sea and steering on any other course than due east or due west.—*Sir W. Thompson.*

NEW APPLICATION OF RAPID OXIDATION BY WHICH SULPHIDES ARE UTILIZED AS FUEL.

By JOHN HOLLWAY.

This process has for its object the utilization of the heat generated by the rapid oxidation of certain mineral substances which have not hitherto been used as sources of heat for smelting operations. The heat thus obtained is employed in the reduction of the furnace charge, which may be composed partly of sulphides and partly of siliceous ores. A current of air is forced through molten sulphides, by which means they are very rapidly oxidized. Great heat is thus developed, rendering the process of smelting a self-supporting operation; therefore, no extraneous fuel is required, excepting that employed in raising steam for the blowing engines; where, however, water power is available, steam can be dispensed with, in which case all the carbonaceous fuel necessary for the operation is a little coke to start the furnaces, which stands in the same relative position to the ores as wood does to coal in the lighting of an ordinary fire.

It is well known that pyritous minerals are readily combustible, but the best means of utilizing the heat-producing property of metallic sulphides is not so apparent as would at first sight appear. Of these sulphides only iron pyrites is sufficiently combustible at a low temperature to burn in the open air, the mass being raised to the temperature at which the oxidation takes place solely by the union of sulphur and iron with atmospheric oxygen. In Spain there are numerous deposits of poor cupreous pyrites, and the Rio Tinto and Tharsis Companies annually treat, at their mines, about one million tons for the extraction of copper only, which does not average 2 per cent. The process employed consists essentially in roasting the pyrites in heaps in the open air, dissolving out the copper from the roasted material and precipitating it from the solution by means of iron. These operations extend over several months; any gold or silver contained in the ore is lost, and the iron and sulphur are also wasted. The sulphur passes into the air as an obnoxious and annoying gas, desolating the country for miles around the works.

From the earliest ages carbon has been considered a necessity in all

metallurgical operations. The first reduction of metals by means of carbon forms a connecting link between the age of stone and the commencement of civilized art. It is well known that carbon burns at widely varying temperatures, as for example, in our bodies, in a common coal fire, or in a furnace. A great deal of thought has been devoted to the subject of economizing carbonaceous fuel, and great advances have been made in this direction; yet the expenditure of coal or coke necessary, say to melt a given quantity of metal, still far exceeds the theoretical limit. The main causes of this discrepancy may be accounted for as follows:

1. Only part of the oxygen of the air passing into furnace acts on the material to be burnt.
2. The oxygen is not brought in contact with the combustible matter with sufficient rapidity to obtain the necessary temperature for the operation.
3. Gases pass off hot and unburnt. These are now, however, frequently utilized.

There is one metallurgical operation in which the first two sources of loss are avoided, viz., "Bessemer's," where, by blowing air through molten crude iron, a very high temperature is attained by the combustion of small quantities of carbon and silicon contained in the crude iron; this is, however, not the case in the process of puddling, where the oxidation is spread over a considerable period of time, although the same constituents are frequently burnt in similar proportions. But even in the Bessemer process the carbon is only half burned, and a large amount of heat escapes with the carbonic oxide and nitrogen.

When, however, thin streams of air are forced through molten sulphide of iron, lying on a tuyère hearth, a high temperature is produced by the perfect combustion which ensues in the midst of the sulphides, and no unburnt gases, excepting nitrogen and sulphur vapor, escape from the surface of the molten mass. The hot nitrogen and sulphurous acid may be caused to act upon iron pyrites and other mineral matter, and when pyrites are thus heated, an atom of sulphur held in feeble combination is in great part expelled, and thus is obtained molten protosulphide of iron, which is subsequently burnt by the oxygen of the air driven in at the lower part of the furnace, thereby producing the heat necessary for continuing the operation. The process may be defined as a system of fractional oxidation, in which the numerous constituents of a complex furnace charge can be separated from

each other and concentrated in different parts of the apparatus, the heat necessary for the operation being obtained by the combustion of a portion of the less valuable constituents.

The principal ores of all our ordinary heavy metals, except manganese and tin, are sulphides. Iron, though largely occurring in an oxidized form, is abundantly found in combination with sulphur; and bisulphide of iron, or iron pyrites, is an example of sulphurous and combustible minerals. Associated with iron and sulphur in iron pyrites are invariably found small quantities of other metals, notably cobalt, nickel, copper, silver, gold, lead, zinc and arsenic. Of these, zinc is almost as combustible as iron itself, while lead and arsenic readily volatilize as sulphides, and cobalt, nickel and copper are distinctly less readily oxidizable than iron, while silver and gold do not oxidize under these conditions; hence, in supplying air to such material, the iron is the first of the elements to suffer oxidation, so that if the oxidation be arrested before the whole of the iron has been burnt, the cobalt, nickel, copper, silver and gold present will be found in the unburnt portion. This principle finds a parallel in the Bessemer process of treating pig-iron for the manufacture of steel, where a current of air is caused to bubble up through a bath of molten crude iron, the silicon is first oxidized, and is closely followed and to a great extent accompanied by the carbon, and no large amount of iron suffers oxidation, until the whole of the silicon and carbon have been burnt out of the molten material.

The experiments made at Messrs. Cammell's works, at Penistone, in a Bessemer converter, have proved that by blowing air through molten sulphide of iron, the iron and a portion of the sulphur are oxidized, and if the oxidation is arrested before the combustion of the iron is complete, a heavy matt or regulus is obtained, which contains but a small proportion of the iron of the ore, but practically the whole or the greater part of the copper and other less oxidizable metals. In one of these experiments the molten sulphides were run into the converter from a cupola in which they had been previously melted, and the temperature was kept up until the operation was discontinued, viz., for a period of ten hours, without the use of any carbonaceous fuel, the heat being entirely derived from the oxidation of the iron and a portion of the sulphur of the lumps of pyrites, which were continuously thrown into the mouth of the converter. A Bessemer converter being unsuited for the collection of the gaseous products, the later

experiments have been made in a series of cupola furnaces belonging to Messrs. John Brown & Company. These experiments have proved the possibility of obtaining a valuable regulus, a slag nearly free from copper, and a considerable quantity of crude sulphur. M. Pourcel, the well-known chemist of the Terrenoire Company, has also made some very interesting experiments, having treated by this method a cupriferous sulphide of antimony containing lead and zinc, using heavy spar and silica as fluxes; he obtained a regulus containing the whole of the copper in the form of sulphide, a slag of light specific gravity, and the lead, zinc and antimony as two separate sublimes which were condensed in different parts of the apparatus, owing to the superior volatility of sulphide of lead over the oxides of antimony and zinc. In the experiments at Penistone and at Sheffield a cold blast of air was employed, and the gases which passed from the converter or furnace into the open air carried away with them a large amount of heat. In practice, however, it would be economical to employ a hot blast, which could be heated by the waste heat from the escaping gases. It is remarkable that the least valuable metals, viz., iron and zinc, generate by their combustion the largest quantities of heat.

The process may be employed for the reduction of even the more volatile metals; for example, Mr. A. H. Allen, of Sheffield, has thus obtained metallic antimony simply by the oxidation of sulphide of antimony. It is well known that sulphide of lead reacts upon oxide of lead with the production of metallic lead and sulphurous acid. If, therefore, a limited amount of air is blown into molten sulphide of lead, the oxide thus formed in the lower part of the furnace will, in passing upward, come in contact with the hot sulphide of lead, and metallic lead will result, with the evolution of sulphurous acid. The furnace having a quiescent hearth below the tuyères, the metallic lead will collect there, and can be from time to time withdrawn. A limited amount of air must be employed, because if it is driven in too quickly, the sulphide of lead will rapidly distil off. In thus treating argentiferous lead ores, the silver (and gold if present) would be found with the first metallic lead reduced. When thus treating galena the furnace should have a basic lining.

The process is peculiarly suitable:

1st. For the treatment of metalliferous substances which cannot be advantageously treated by other processes. For the extraction of sul-

phur by distillation, and simultaneously for the concentration and separation of cobalt, nickel, copper, silver and gold from minerals in the form of metallic regulus; while lead, zinc, antimony, arsenic, etc., accrue in the sublimates.

2d. For the treatment of complex ores, for example, grey antimonial copper ores, such as those experimented on by M. Pourcel. Ores similar to those worked at the well-known Bottino Mines, Seravezza, in the Italian Appennines, which contain thirteen or fourteen heavy metals, including silver and lead, for which latter alone they have been worked for centuries. The blende of lead mines in Derbyshire termed "muck," usually thrown away by the miners, because the large quantity of lead with which it is associated renders the zinc obtained from it worthless.

3d. For the treatment of auriferous and argentiferous pyrites. It is well known that in practice it is not possible to obtain the whole of the gold from pyrites by amalgamation with quicksilver, because the presence of sulphur and arsenic sickens and flours the mercury, whereas by fusion the whole of the silver and gold present is obtained.

4th. For the treatment of pyrites containing even only small percentages of cobalt, nickel and copper, which are thus concentrated into a rich regulus, whereas this result is now only obtained by very tedious processes of alternate roasting and reduction. Such ores containing 10 per cent. and even 12 per cent. of copper exist in South America and many other parts of the world, but are not at present capable of economic treatment, owing to the difficulty of obtaining a sufficient supply of cheap fuel. The process can also be advantageously applied to the treatment of richer ores of copper such as are at present smelted at Swansea.

5th. For the treatment of poor lead ores. If such ores are added to a furnace charge of cupreous pyrites, the silica they contain will be utilized and combine with the resulting oxide of iron to form slag, the galena will be volatilized and be recovered as a sublimate, while any silver present will enrich the regulus. At present, by a costly process of crushing and washing these ores, the galena is concentrated, although a large proportion is left with the *débris*, and passes with the water into the streams, rendering the existence of fish in such waters impossible. The water power now used for washing the ore could, in many cases, be employed for producing the blast.

When thus treating cupriferous iron pyrites, four products are obtained :

1st. A matt or regulus containing from 30 to 50 per cent. of copper, any traces of cobalt, nickel, silver or gold the ore may contain, the rest of it being iron and sulphur; it has a specific gravity of $4\frac{1}{2}$ to 5.

2d. A slag consisting of silicate of iron from the resulting oxide of iron combined with the siliceous matters contained in the ore and the fluxes added.

3d. Sublimed sulphur, more or less mixed with volatile compounds of lead, zinc and arsenic.

4th. Sulphurous gases consisting mainly of sulphurous acid and nitrogen.

The regulus closely resembles, and will replace, the coarse metal of the Swansea copper process, which is now only obtained at considerable cost of labor, time and carbonaceous fuel. When, however, sulphides of iron and copper present in the bath are treated continuously by a blast of air, a point is at length arrived at when the whole of the iron is oxidized, and the regulus in the bath consists of sub-sulphide of copper. If, now, a limited supply of air is introduced, the copper is reduced to the metallic state with the evolution of sulphurous acid.

The slag obtained in the Penistone experiments was essentially silicate of iron, containing about 50 per cent. of iron and 29 per cent. of silica. It had a density of about 3.8 to 4, and was in composition somewhat allied to the copper-smelter's ore furnace slag and to the tap-cinder of the iron-puddler. By the addition of calcareous materials, the specific gravity of the slag is so reduced as to cause it to separate readily from the regulus which collects below it. In one of the later experiments, when lime was used, the proportion of copper lost in the slag was very small. This is, of course, a most important point, for when dealing with ores containing but little copper, the presence of even a small percentage in the slag means the loss of a considerable proportion of the copper present. These slags can be utilized for the manufacture of steel, being practically siliceous iron ores free from phosphorus, and their reduction in a blast furnace can be profitably effected, as the proportion of iron present is high as compared with the weight of the material; indeed, it may be possible to reduce them while in a molten state.

By re-subliming the crude sulphur, it can be freed from all impurities except arsenic, and at the works of Messrs. John Hutchinson & Co., Widnes, this is eliminated by means of polysulphide of calcium.

As a certain proportion of the sulphur of the minerals suffers com-

bustion, the resulting sulphurous gases contain from 14 to 15 per cent. of sulphurous acid, and hence the proportion of sulphurous acid to nitrogen is nearly identical with that of the gases produced by roasting pyrites in the kilns employed by vitriol manufacturers, and can therefore be used with equal advantage for the production of vitriol in leaden chambers. This appears to be the simplest solution of the great problem how to smelt copper without causing a nuisance to the surrounding neighborhood, although a similar result might be obtained by collecting and liquefying the sulphurous acid.

The more incombustible materials it is found practicable to employ without too great a loss of temperature, the wider will become the application of the process; for there are many ores, including silicates and carbonates, containing metals in the form of oxides, which might be conveniently smelted by mixing them with a sufficient proportion of pyritous ores to effect their reduction; in fact, one of the chief practical questions connected with this process is how far it may be trusted to effect the smelting of ores or furnace charges containing comparatively moderate proportions of sulphides. It is evident that it will almost entirely obviate the necessity for using carbonaceous fuel, at least as far as the production of a regulus is concerned, and consequently the localities in which smelting operations may be advantageously carried on are thus greatly multiplied. One of its chief merits is that it is equally applicable with comparatively little extra cost in the working, to very poor and very rich ores, for however small the resulting regulus, it will contain nearly the whole of the cobalt, nickel, copper, silver and gold present in the furnace charge, while any lead, zinc, antimony and arsenic will be obtained as sublimates.—*Nature*.

Confirmation of Prediction.—M. A. Gorgen has succeeded in making an artificial deutoxide of manganese, having all the properties and characteristics of polianite. It was obtained by heating nitrate of manganese, very slowly and for a considerable time, at a temperature of from 155° to 162° (311° to 323.6° Fahr.), in a glass phial placed in a bath of oil or paraffine. His experiments confirm the hypothesis which was published in 1860 by MM. Sainte-Claire Deville and Debray.—*Comptes Rendus*. C.

THE LIGHT AND ENERGY OF ELECTRICITY AND GAS.

By J. T. SPRAGUE.

Some very remarkable statements were made before the Committee of Parliament on Lighting by Electricity. These statements are embodied in the report, and having gone the rounds of the press without examination or comment, they will, no doubt, be adopted as settled facts. It is, therefore, very desirable that they should be examined, and that an understanding should be arrived at as to how far they are reliable, and in what sense they are true. We will, therefore, commence with the remarks of Sir William Thomson.

1746. We are anxious to obtain your opinion upon various points connected with electric lighting; perhaps you will let me go to the root of the matter, and ask you to tell us the energy which is used and exhibited as light in the production of the electric arc?—The energy which is actually used in the electric arc is about 1 horse-power per 2400 candles-power, or even more than 2400 candles-power, according to the dimensions and other circumstances of the electric arc.

1747. That is to say, 1 horse-power, if fully employed, produces 2400 candles or more?—Yes, 1 horse-power actually in the electric arc; 1 horse-power spent in stirring the luminiferous ether between the carbon points and on the surfaces of the carbon.

1748. Have you at all calculated the energy appearing as light in the case of the combustion of gas?—1 horse-power of energy in the combustion of gas produces about 12 candles-power.

1749. And one horse-power converted into electric light produces 2400 candles?—Yes.

1750. As these are rather startling figures, perhaps you will explain to the committee how you arrive at such results?—Sir William's reply is too lengthy for full quotation, as the greater part of it is unimportant; he concludes by saying: "The upshot of all is that, allowing the practical estimate of 1 horse-power actually spent in driving the engine to produce 1200 candles, which has been realized, I estimate that one-half of that power goes to the electric arc, and one-half is lost in heating different parts of the machine. *This then gives 2400 candles for 1 horse-power*, which is the figure of my answer. In respect to gas I

have taken 4 candles per cubic foot of gas per hour. I have taken the heating power of gas at 12,000 centigrade units per gramme; I have taken the specific gravity of the gas as half that of air, and calculated accordingly. I have thus calculated the *whole heat of the combustion of gas*, from the amount of that per second of time, and reduced it to horse-power. Thus I arrive at the figure which I gave in my answer, *i. e.*, 1 horse-power actually spent in warming the air and stirring the luminiferous ether in a gas flame of 12 candle-power."

The committee in their report remark that there is some difference of opinion between the scientific and practical witnesses, and it is not to be wondered at if the foregoing is to be taken as a type of scientific evidence. In fact, the statements are all true, but they are so arranged as to constitute a complete chain of special pleading, and to convey an absolutely false impression of what the facts themselves really mean. The statements are *true as to the energy actually in the lights*. The impression they produce is *false as to the energy necessary to produce the lights*.

There are two ways of considering energy, as with most other things. There is the *potential* or theoretical energy of a combustible; that is to say, the total heat capable of being produced by its union with oxygen. This potential energy of coal, for instance, is about 13,000 centigrade heat units per pound. In commercial language, we may call this the *gross* energy of the coal. There is, again, the *practical* energy of the combustible, a function of the boilers and engines. For instance, average steam engines give a horse-power for seven pound of coal per hour; this, in commercial language, may be called the net energy of the coal.

Now, what Sir William Thomson has done is just this: he has charged the gas light with the gross energy, and the electric light with the net energy, as indicated by the italics in his evidence, and people who do not understand this, like the writers in the daily press, of course imagine that these figures so seriously stated are really true.

Now let us see what would come of an equitable comparison, using, as far as possible, Sir William Thomson's own figures.

1 horse-power is 33,000 ft.-lb. per minute, or 1,980,000 per hour. Expressed in heat units of 1 lb. water 1° Cent., which equals 1390 ft.-lb., 1 horse-power per hour equals 1424·5. This, then, is the potential energy of the 4 cubic feet of gas, giving 12 candles light.

To put the 1 horse-power of energy into the electric are another 1

horse-power is of necessity expended in the circuit and must be charged, because the gas compared with it is the whole amount necessary. But to produce 1 horse-power in a steam engine involves a consumption of coal varying from 2.5 pounds, in the most perfect and expensive engines known, to 8 and even 10 pounds in common engines; let us take 4 pounds as a very fair engine's work and we have 8 pounds coal expended in generating the 2400 candles mentioned. Now, the potential energy of 1 pound of average coal is 13,000 heat units, or, in 8 pounds, 104,000.

Instead of having the energy per candle:

$$\text{Gas, ... } 1424.5 \div 12 = 118.7$$

$$\text{Electricity, ... } 1424.5 \div 2400 = 0.597$$

This being what Sir William Thomson makes it appear to be, we have, by equitable comparison:

$$\text{Gas, ... } 1424.5 \div 12 = 118.7$$

$$\text{Electricity, ... } 104,000 \div 2400 = 43.3$$

Even then we have omitted a very important element of consideration: the gas light needs no machinery, no capital outlay, no skilled attendance; the electric light wants all these, and if they do not form an element of the scientific calculation as to potential energy involved in the two cases, they enter very largely as factors in the practical calculation as to the potential cost. Hence the difference in the practical and so-called scientific opinions noted in the committee's report.

The comparisons made are, however, intrinsically erroneous, because made between electricity in its best conditions on the large scale, and gas in its worst on the small scale, and it is well known that in all things the small scale is most costly, whether we consider the expenditure of money or of energy. But, in addition to this general principle the comparison is not really made with an electric arc having 1 horse-power of energy expended in it. The estimate is made from a light having 3 or 4 horse-power in it; in this way the value is arrived at "of 1 horse-power actually employed in driving the engine to produce 1200 candles," and as only half this energy is in the arc, the light equal to 1 horse-power is taken as 2400; but it is well known that to produce a light of 1200 candles in a single arc requires 2 horse power of engine, and in those conditions the 1 horse-power energy would be actually in the arc, and the efficiency would be:

$$\text{Electricity, ... } 104,000 \div 1200 = 86.6.$$

as against gas 118·7 per candle, and this when setting the production of a 12-candle light against one of 1200.

It may be well to explain why the actual energy expended in the luminous area is so much smaller with electricity than with any combustible such as gas. In the case of combustion the energy has to be employed in heating the products of the combustion, steam and carbonic acid and a large bulk of neutral nitrogen from the air; these all flow rapidly away and carry off the heat. The very same loss has to be met in the electricity when derived from combustion, but the loss occurs, not in the light, but in the furnace and in the wires; here pure energy is collected and transmitted to the arc, where it makes its appearance as light unencumbered by the products of the processes of the transformation of latent energy into light and heat. Still, as the loss has to be incurred in both cases, both the lights when compared must have the total energy needed for their development taken into account.

The same witness expressed opinions as to the transmission of power from central engines to different parts of towns by means of electricity, but as Mr. Siemens gave the figures upon which these opinions are founded, we may now pass on to examine these. Mr. Siemens, comparing the cost of gas and electricity, says: "(136.) Making the unit of comparison 1000 standard candles per hour, the results are striking. An Argand burner produced 1000 standard candles of light per hour, with a consumption of 312·5 cubic feet of gas; and to make this, 56 pounds of coal would have to be used in the retorts. (139.) In the case of a medium dynamo-machine driven by a gas engine, 19·5 cubic feet of gas produce 1000 standard candles during one hour; and the consumption of coal necessary to produce this gas is 3·26 pounds. (141.) And in the case of the naked light the consumption of coal is very nearly the same?—It is very nearly the same: it is 13·3 pounds in the gas engine, and 12 pounds in the steam engine, showing that the gas engine is really a very economical engine, and has moreover the advantage over the steam engine, that no boiler is employed, and that the consumption of gas commences and ceases the moment the motion of the engine commences and ceases."

It will be seen presently that this advantage of the gas engine is very much understated, because the coal corresponding to the gas is largely overestimated.

The comparison between the relative weights of coal consumed is really of little importance, because the real thing to be considered is

the relative costs. The cost of gas is, of course, greater than that of the mere coal it represents, because its price includes labor, capital and distribution; on the other hand, the coal consumed in the other case must be charged with wages, etc., necessary for its consumption to place it on the same footing as the gas with which it is compared. But when any comparison is made or any line of argument adopted it ought to be correctly worked out.

Now, instead of an Argand burner giving the light of 1000 candles on a consumption of 312·5 feet of gas per hour, this value is calculated from the work of 62 Argand burners, each consuming only 5 feet per hour of 16-candle gas. No burner of 1000 candle-power has been made. But burners giving 250 candles on a consumption of 60 feet are made, so that we know that 1000 candles can be obtained from 240 feet instead of 312·5. But Mr. Siemens commits a more serious injustice when he charges against the gas the whole of the coal put into the retort, allowing nothing for the coke and tar, which form part of the actual coal with which he is comparing the gas. In this way he obtains a consumption of 15 pounds of coal per hour with gas as against 8 pounds consumed in a steam engine to develop the 2 horse-power necessary to develop 1000 candles in one electric arc.

A ton of average coal gives 9600 feet of gas of 0·450 sp. gr. which equals 331 pounds of purified gas per ton; about 1300 pounds of coke are produced, and if we reckon the excessive consumption of one-third of this in the furnaces and charge the whole of this against the gas produced we shall find that we get about 12 feet of gas for each pound of coal which has disappeared—that is to say, 100 cubic feet of gas represented, at most, 8 pounds of coals. This reduces Mr. Siemens' 56 pounds per 1000 candles to 25 pounds on the consumption of 5 feet Argands, and to 19 pounds on the actual consumption in 4 of the 250 candle burners.

This shows the great economy of the gas engine as compared with the steam engine. Gas engines are already in use which develop 1 horse-power per 21 feet of gas, which represents at most 1·6 pounds of coal, and this efficiency is realized in small engines. But the very best steam engines of large dimensions have never realized more than 1 horse-power for 2·5 pounds of coal, and this only with great attention. Ordinary engines consume 8 and 10 pounds per hour per horse-power, and a consumption of 4 pounds would be very good work for any engine employed under general conditions analogous to those for which

gas engines would be used. The reason of this economy is that the potential energy of the fuel is converted directly into mechanical energy in the cylinder by the act of combustion; only so much is necessarily carried off as goes with the heated products containing only the small quantity of vapor due to the hydrogen in the gas. With steam all this loss occurs in the furnace of the boiler, and in addition there is the immense quantity carried off in the escaping uncondensed steam.

We now come naturally to the question of transmitting power. Mr. Siemens says: (200) "I believe it would be the cheapest mode of transmitting power to a considerable distance. The experiments which we have made give a result of a loss of 50 per cent., that is to say, 5 horse-power applied to a dynamo-machine produces, roughly speaking, $2\frac{1}{2}$ horse-power at a distant point; it would follow that, say, 100 horse-power engine at a central station, which could be worked with a consumption of 2.5 pounds per horse-power, would produce at a number of points, power at the rate of 5 pounds per horse-power."

Mr. Siemens thinks more favorable results may be hoped for than 50 per cent. return; but it is a pretty general law in electricity that the resistances must be equal in generator and utilizer, and there are reasons for this, which the resistance expresses, though it is itself an agent and not the cause; hence 50 per cent. is the full theoretical efficiency, allowing nothing for loss in the conductor and by leakage; in actual working the total efficiency would be more likely 30 to 40 per cent.

But giving electricity its utmost claim, and the use of the best engines known, we have a consumption of coal of 5 pounds per horse-power delivered, as against 1.6 pounds per horse-power delivered by gas. But we have to consider something besides the theoretical consumption of coal. The 21 feet of gas at 4s. per 1000 costs 1d., while 1d. would buy 9.3 pounds of coal at 20s. per ton. But the 1d. in the case of gas covers the whole cost of the delivery of the energy of the coal to the machine which uses it. In the case of coal it represents, on the other hand, energy which has to be delivered; to place the electric energy of that coal on a par with the gas we have to provide and pay for:

1. The capital outlay, wear and tear of the steam engine, and its attendance.
2. The dynamo machine which generates the electric current, and all its subsidiary expenses.

3. A conducting system, the conditions and difficulties of which are as yet absolutely untested.

4. The general expenses of management and the profits of the undertaking.

These simply represent the gas works and mains, and the expenses and profits of the gas company, all of which are included in the penny charged for the horse-power of gas. The consumer would have in either case to provide a gas engine or dynamo-electric apparatus, the costs of which would be about the same.

It is quite certain that the expenses of all this would raise the cost of the 5 pounds of coal consumed at the central station to considerably more than the penny; in fact, they would be so great that it is not surprising that no one has yet ventured to dispute the remarks made some time ago on Mr. Siemens' proposal to transmit the energy of waterfalls 30 miles distant, or of the coal at the pit's mouth. The power costing nothing at the 30 miles distance, it would be better economy to allow to run to waste, its delivery would cost more than the expenses of carriage of coal, which has to be paid for, and its conversion into gas in the different towns as required.

As the writer himself is working at the problem of electric lighting, and is the patentee of machines which will be brought into operation in a little while, it will be understood that there can be no intention to depreciate the importance of these applications of electricity. But the statements examined will no doubt be utilized ere long by the various prospectus writers, who are waiting their opportunity; and it is of great importance that their actual meaning should be understood and the real truth be presented to the public understanding.—*English Mechanic*.

New Application of Paper.—In the Portsmouth dry-dock a vessel was hauled up for repairs, and it was observed that a portion of the hull, to which a piece of paper adhered, was free from grass and mussels. Experiments were instituted which led to an application for a patent for paper sheathing. As it can easily be impregnated with poison, it will probably act as a protection against borers as well as against ordinary fouling.—*Fortschr. der Zeit.* C.

THE IRON AND STEEL PRODUCTION OF AMERICA.

One of the most important industries of the country, and one which promises to attain under the brighter skies of the present year even greater proportions than it now has, is the iron trade. While in England the iron trade was greatly prostrated last year, and continues to be in a state of extraordinary depression, bringing hardship and suffering to many thousands of operatives, its condition in the United States in 1878 showed an encouraging improvement over 1877, and the prospects of 1879 are hopeful.

Mr. James N. Swank, the secretary of the American Iron and Steel Association, reports that our founders have no present fear of foreign competition. The iron manufacturers of England, indeed, have reluctantly given up the United States market as hopelessly lost, and this loss has greatly helped to depress the industry in that country and to increase the gloom which rests over its future. Whereas our imports of railroad iron amounted to nearly 20,000,000 dollars in 1872, in 1878 they fell off to the insignificant sum of 530 dollars.

The statistics of the iron trade of the United States show that our production of pig iron in 1878 was 2,577,361 tons, against 2,314,585 tons in 1877, though there were 16 fewer furnaces in blast at the close of last year than at the close of 1877. This, of course, shows that those actually at work produced more on an average than in the latter year; but the prices of pig iron are so low that many furnaces were run without a profit. While in both steel and iron rails there was an improvement, in pig and bar iron there was a decline from the exceptionally low prices of 1877, in one case a decline of 1 dollar 50 cents a ton, and in the other of 2 dollars 24 cents a ton. The founders hope, however, that prices have at last reached the lowest point to which they can fall, and anticipate a continuance of the increased demand which characterized the old year.

The manufacture of Bessemer steel made healthy progress during 1878, and the prospects for 1879 are very bright. The rapid development of this industry in the United States has put us in such a position that we are now independent of the rest of the world in the steel matter, and foreign competition has no terrors for our makers. Like the rest of the iron men they are satisfied with the present tariff,

and ask no greater odds than they now have. Some of them even think they would not suffer were the duties lowered, and they share the conviction so generally entertained in England that the United States will never again be a valuable customer for the British manufacturers of Bessemer steel. The perfection of our steel furnaces has lately won favorable mention in Germany, where the steel manufacturers are clamoring for a protective duty, which, it seems likely, they will not fail to get, for they have Prince Bismarck on their side. Dr. Wadding, a well-known German statistician, has ascertained that Prussia is so far behind the United States in steel making that while the latter, with twenty-two converters, produced in 1875 over 375,517 tons of steel, the former, with thirty-five converters in operation, only produced 284,591 tons, showing a production nearly double in our favor; and he ascribed our greater turn-out entirely to the superior mechanical appliances possessed by our works. In 1877 we manufactured of steel ingots 560,587 net tons, and of Bessemer rails 432,169 tons. In 1878 the product was 732,000 net tons of ingots and 600,000 tons of rails. This is a very handsome gain, and it justifies the cheerfulness which prevails among the manufacturers of steel. Putting the iron and steel rail production of the year together, the total amounts to 930,000 tons, a total only once exceeded in our history, and that in 1872, when the product reached a million. Even that immense manufacture will probably be equaled, if not exceeded in 1879.

The year 1878, on the whole so encouraging to our future iron industry, was one of great disaster to that of Germany, and the present movement for protection in that empire largely springs from its misfortunes, which have been accumulating since 1875. Since 1876 things have been going from bad to worse, and now, in the words of a writer in the *London Times*, the iron trade in Germany is in a state "worse, unquestionably, than that of any other country." The famous Krupp works at Essen, the largest in the world, employing two years ago 10,500 workmen in factory and 5000 more in the mines and blast furnaces, have suffered heavily, while between April, 1873, and April, 1877, the number of workmen employed by twenty-two of the principal companies, exclusive of Krupp's, fell off from 27,700 to 14,600. The German founders are dissatisfied with this state of things, and with Prince Bismarck as their powerful ally they are working for a protective tariff, which, the prospects are, they will assuredly get.

Meantime the British Iron Trade Association is doing its best, through Lord Salisbury, to defeat their efforts, but with little hope of success. How much Great Britain would lose by the imposition of protective duties on iron by Germany is shown by the statistics of her exports of iron to that country. During 1877 Scotland sent her 127,-355 tons of pig iron, and England 200,000 tons, while of English steel rails Germany took 21,365 tons.

The following are extracts from the report of the American Iron and Steel Association :

“In nearly all branches of the domestic iron and steel industry enumerated there has been an increased production in 1878 over 1877; but this increased production has been accompanied by a decrease in prices. At no time in the history of the country have prices for iron and steel been so low as they were in 1878, excepting perhaps in Colonial days, when the price of pig iron was lower. The year 1878 witnessed an increased production of pig iron in the United States over the year 1877, as 1877 had witnessed an increased production over 1876, which was the year of lowest production since the panic of 1873. The production of pig iron in 1878 was 2,577,361 tons of 2000 lbs., showing a gain over 1876 of nearly half a million tons. If a similar rate of increase be maintained in 1879, as we have no doubt it will be, the production of this year will equal that of either of the exceptionally productive years, 1872 and 1873, while a much less rate of increase will carry our production in 1880 above 3,000,000 tons.

“It is demonstrated that the consumption of pig iron in the country has greatly increased since 1876; and this increased consumption is not wholly accounted for by the growth in the past two years of the Bessemer branch of our steel industry, rapidly as it had been developed. The production of iron rails and all forms of rolled iron was but little greater in 1878 than in 1876, and fair to infer that the increased consumption of pig iron was partly due to increased activity in our steel works, and partly to improvement in the general business of the country, as shown in increased business done in our foundries and machine shops. Prices of pig iron declined steadily in 1877 and 1878, as they had previously since 1872. The average yearly price of No. 1 anthracite foundry pig iron at Philadelphia in 1872 was 48 dollars 87 cents. In 1878, 17 dollars 62 cents. Of the total production in 1878, of 2,577,361 net tons of pig iron, 1,092,870 tons were made

with anthracite coal; 1,191,092 tons were made with bituminous coal and coke; and 293,399 tons were made with charcoal.

"For two years past there has been a steady increase in production of pig iron from bituminous coal and coke, while of charcoal iron the production has declined from 575,000 tons in 1874, to 293,399 tons last year. Less than fifty years ago all the pig iron produced in the country was made with charcoal; in 1878, less than 12 per cent. The use of coke as a blast furnace fuel has steadily increased, and been invading districts heretofore extensively appropriated by anthracite coal.

"Fifteen States increased their production of pig iron in 1878, while Maine, Massachusetts, Maryland, Michigan and Missouri decreased production. North Carolina, Texas and Indiana made pig iron 1877, but none in 1878. None of the Territories made pig iron in 1877 or 1878. Of the total product of 2,577,361 tons in 1878, Pennsylvania made 1,342,633 tons, or just 52 per cent. No new iron-making territory has been developed during the past few years, except the Hocking Valley, in Ohio, which produced 65,690 tons of pig iron in 1878, against 23,895 tons in 1877.

"At the date of preparation of this report in April, 1879, nine new furnaces were in course of erection, but more furnaces are being abandoned than are being built, which shows the number of blast furnaces in the country to be decreasing.

"The Secretary has a list of 692 furnaces in the country at the close of 1878, some of which he adds will never again make pig iron. Of this large number only 265 were in blast at the close of 1878. At the close of 1877 the number in blast was 270. As the production of pig iron was 262,776 tons greater in 1878 than in 1877, it is clear from a comparison of the number of furnaces in blast in each of those years that our furnace practice greatly improved in 1878.

"The improvement in blast furnace practice since the panic struck the country in 1873 is indeed most striking, as shown by statistics of production of the blast furnaces of the country in that year as compared with that of 1878. In the former year the average product of each furnace in blast was 6996, while that of 1878 was 9726 tons, showing a gain of nearly 40 per cent. in five years.

"Part of this is due to larger furnaces, and part to greater skill in all details of furnace management, and a part to increased use of better ores and of Connellsville coke. The production of Spiegelseisen.

which is so necessary in the manufacture of Bessemer steel, was carried on last year in but two States, viz., Pennsylvania and New Jersey, and but 10,674 tons was produced.

"The production of iron and steel rails in the United States in 1878 was 882,685 net tons. This product has been but twice exceeded in the history of the country, in 1872 and 1873. In the former year it reached 1,000,000 tons. The increased production in 1878 over 1877 was 117,976 tons. The product of 1878 was composed of 550,398 tons of Bessemer steel rails; 322,890 tons of iron rails, and 9397 tons of open-hearth steel rails. The production of Bessemer steel rails was 118,229 tons greater in 1878 than in 1877, while that of iron rails was 9650 tons less. Open-hearth steel rails appear in the statistics of last year's rail production for the first time. In 1879 we shall probably produce as many rails as in 1872, when we made 1,000,000 tons. The production of street rails in 1878 is included in the aggregate production for the year, and amounted to 9229 tons. Nineteen States and the Territory of Wyoming made rails in 1878. In 1877, Michigan dropped out of the list of rail-making States, and in 1878 Colorado entered the list. Utah has a mill for re-rolling iron rails.

"In spite of the hard times, it will be seen that the iron industry is steadily making gains in the West.

"Bar-iron sold at Philadelphia, during 1878, and the country at large, at $1\frac{9}{10}$ to 2 cents per pound, while in Pittsburg the average for the year was $1\frac{3}{4}$ cents, or 39.20 per ton. The price of nails at Pittsburg fell steadily during 1878, and in December touched the extraordinary low figure of \$1.85 per keg. At date of report the nail trade at Pittsburg and other points West was much demoralized on account of over-production, the price being about \$1.90.

"The development of the steel industry in the United States is one of the marvels of our time. At the outbreak of the war of the rebellion the manufacture was indeed in its infancy, but it was advanced with gigantic strides until, in the years of 1875 and 1877, the production of crucible and all other kinds of steel, except Bessemer and open-hearth steel, exceeded 52,000 tons in each year. Last year the production fell off a little, showing 51,462 net tons; but including Bessemer and every kind of steel produced, we have the grand total of 819,814 tons, which, coupled with the low prices at which it has been sold, should convince every American of the wisdom of the protection

policy, and of the extreme folly of further refusing to recognize its benefits.

"Of the eleven Bessemer steel works in the country only one, the Vulcan, of St. Louis, was idle last year. Down to the close of 1878 this country had produced a total of 2,145,595 net tons of Bessemer steel rails. Blooms and billets from ore are made mainly in the Champlain district of New York; blooms from pig and scrap iron are made mainly in Pennsylvania. Of this class of iron the production is not as great now as five years ago.

"The decline in pig-iron was 59 per cent.; in bar-iron 49 per cent.; in steel rails 65 per cent., and in iron rails 56 per cent.

"For the first time steel rails appear among the exports for 1878, the quantity exported being 249 net tons. There was a decline in our export of stoves from \$141,361 in 1877, to \$98,837 in 1878. The exports of locomotives increased from 64 in 1877, to 82 in 1878, and a large increase in the exports of stationary engines and boilers.

"The cessation of war in Europe caused a heavy decline in our export of fire-arms as compared with 1877. The aggregate value of our exports of iron and steel, and manufactures of the same to all countries in 1878 was \$13,260,369. This, however, does not include the following items of manufacture, and which are largely composed of iron and steel, agricultural implements, scales and balances, sewing machines, fire engines and apparatus. The export of these articles amounted to \$4,732,126 in 1878, showing a gain of \$843,930 over 1877."

Production of iron in tons in the United States in the past two years:

	1877.	1878.
Pig iron, ...	2,314,585	2,577,361
Stocks of pig iron unsold, December 31,	642,351	574,565
Bars, angles, bolts, rods and hoops, . .	720,531	820,837
Plates and sheets, ...	182,242	182,042
Nails in kegs, ...	4,828,918	4,396,130
Iron rails, ...	332,540	322,890
Bessemer steel rails, ...	432,169	550,398
Open-hearth steel rails, ...		9,397
Total production of rails, ...	764,709	882,685
Bessemer steel ingots, ...	560,587	732,226
Crucible cast steel, ...	40,430	42,906
Open-hearth steel ingots, ...	25,031	36,126
All other steel, ...	11,924	8,556
Spiegeleisen (included in pig iron above),	8,845	40,674
Blooms from ore and pig metal, ...	47,300	50,045

Additional Statistics.	1877.	1878.
	Dollars.	Dollars.
Value of iron and steel imports, . . .	9,195,368	8,943,043
“ “ exports, . . .	16,659,675	13,260,369
Miles of railway constructed, . . .	2,177	2,747
Number of immigrants, . . .	130,503	153,207
Production of Lake Superior iron ore in gross tons, . . .	1,025,129	1,125,231
Tonnage of iron ships built (in fiscal years), . . .	5,927	26,960
Net imports on merchandise (in fiscal years), . . .	438,518,130	422,895,034
Domestic exports of merchandise (in fiscal years), . . .	589,670,224	680,709,258
Net imports of specie (in fiscal years), . . .	27,746,915	23,134,074
Domestic exports of specie (in fiscal years), . . .	43,134,738	27,061,885
— <i>New York Sun.</i>		

Anomalies of Terrestrial Magnetism.—An interesting discussion has arisen in the French Academy between MM. C. Flammarion and Marié-Davy, in regard to an unexplained anomaly in the magnetic observations at Paris. In order to correspond with the eleven-year variation, the amplitude of the daily oscillation should have descended, between 1871 and 1878, from 12' to 5'. Instead of this progressive diminution it fluctuated abnormally between 9' and 10'. In order to get more accordant results Marié-Davy proposed to take the difference between the positions of the needle at 3 P.M. and at midnight, but Flammarion objected, because the greatest eastern elongation is generally about 8 A.M., and the greatest western deviation is about 1 P.M. The amplitude of an oscillation should cover the entire range, and should not be arbitrarily limited to two-thirds or three-quarters of the range. Other forcible objections were urged, and among the possible sources of the anomaly attention is directed to the situation of the observatory, at the crossing of two railway lines, and to the methods and hours of observation. In view of the great importance that is now generally attached to magnetic observations, it is important to remove, so far as possible, all anomalies.—*Comptes Rendus.* C.

THE "*POLYPHEMUS*."

The torpedo ram *Polyphemus*, now being constructed in Chatham Dockyard, appears likely to be the most extraordinary ship that has yet been built. She is novel and peculiar alike in form, structure, fittings and arrangement of armor protection, while her weapons of attack are such as will necessitate her being fought differently from any other war ship. Her design was described by the late Mr. Ward Hunt in the House of Commons on the 12th of March, 1877, as being "of a kind as yet unknown in any part of the world, but which has been much talked about, and has been at last forced upon me by that gallant officer who stands at the head of the veteran list of the navy, viz.: Sir George Sartorius, who has shown that although his age is great, his mind is still youthful, and that he is willing to receive new ideas and able to inculcate them."

The leading features of the *Polyphemus* are a strong ram bow, a powerful torpedo battery, great speed and handiness, moderate size, and a small extent of surface above water exposed to the enemy's fire, such portion of the vessel as is above the water line being convex in form, so as to deflect any projectile that may strike it. The appearance she will present, when at sea, will be that of a cylinder, floating on its side and deeply immersed, which is tapered at the ends to form a bow and stern. The top of the cylinder will be 4 feet 6 inches above the water line, and will be flattened over a large portion of its area to form a deck. The whole of this flattened cylindrical surface will be plated over with steel armor, and will cover in and protect the ship and all her machinery and fighting appliances. The ship proper, as she will thus appear, will be surmounted by a light structure carrying a hurricane deck of about two-thirds her length, and upon this deck will be seen a signal mast, funnel, pilot tower, boat and other fittings.

Under water the form of the *Polyphemus* is as strange as it will thus appear above. The cylindrical curvature of the sides is carried down several feet below the water line, and armor-plated to that depth. Below this point the section assumes a V form, and ends in a sharp angle at the keel. It will therefore be seen that a complete cross-section of the vessel is very similar to that of a peg top. The flattened convex curvature of the upper part of the peg top would represent the

part of the *Polyphemus* that is above water, and the lower portion, which ends in a point, would also represent the part of the ship that is below water. If the peg top be imagined to float in water at a depth below where its breadth is greatest and where the section thus begins to curve towards the centre line, a rough idea may be obtained both of the form and proportions of the above and under-water parts of the *Polyphemus*.

The *Polyphemus* is 240 feet long between perpendiculars, 40 feet in extreme breadth, and will have a load draught of 20 feet. Her displacement will be 2640 tons. The convex armored deck will be 4 feet 6 inches above the water line, and will be completely plated over with steel armor 3 inches thick. This armor will be carried to a depth of six to seven feet below the water line. The *Polyphemus* will not be fitted with masts or sails, but will carry a pole for signaling purposes and for making observations from. She will be propelled by twin screws, and will have two pairs of high-pressure compound horizontal engines, which are being constructed by Messrs. Humphreys & Tennant, of Deptford. Each high-pressure cylinder will be 38 inches in diameter, and the low-pressure 64 inches. The stroke will be 45 inches. The boilers will be of the locomotive type, twelve in number, and will be made of steel. They will work up to a pressure of 110 pounds per square inch. It is estimated that the engines will indicate a collective power of 5500 horses, and that the speed of the ship will be 17 knots.

The only offensive weapons the *Polyphemus* will possess are a powerful ram bow and Whitehead torpedoes. She will have no guns at all, except a few light shell guns and Gatlings on the hurricane deck for the purpose of repelling boat or torpedo attack. The ram will consist of a very strong spur, which will project 12 feet in advance of the stem of the ship, and is so placed that it will strike several feet below an enemy's armor. It will be connected to the stem and bow by deep web plates and angles on each side; the former being a continuation of the 3-inch deck armor, which is curved downwards at the bow and carried under water till it reaches the level of the spur. The spur is being fitted so that it may be unshipped and taken off the stem when not required for active use. Under the ram is a torpedo port, which will enable Whitehead torpedoes to be ejected right ahead of the ship. There are also two torpedo ports on each side amidships, from which they will be ejected on the broadsides. The ports and apparatus for

working the torpedoes will be upon the system fitted in the *Vesuvius* and *Glatton*. All the torpedo ports are below water, but it is understood that this under-water attack will be supplemented by torpedo firing above water from the armored deck upon the system adopted in ordinary torpedo launches.

Above the armor-plated portion of the hull a hurricane deck is fitted for about two-thirds of its length. This deck is about one-half the extreme breadth of the ship. Communication is made between the hurricane deck and the interior of the ship by openings cut through the armored deck. The openings thus cut are protected by glacis plates and armor, and by casings, which are carried up to the hurricane deck. The boats are carried upon the hurricane deck, and the ship is steered and worked from it. An armored pilot tower, with protected means of access to the lower part of the ship, is placed at the fore end of the hurricane deck, and fitted with steering wheel, telegraphs, voice pipes, apparatus for firing off the torpedoes, and all other appliances for conning and working the ship. A few light shell or Gatling guns will also be carried on the hurricane deck, as we have stated, for repelling boarders or torpedo boats.

The *Polyphemus* is built throughout of steel. The frames are of Bessemer, and the bottom plating of Lindore-Siemens steel. She is constructed upon the usual system of transverse bracket frames and continuous longitudinals, and has a double bottom the whole length of the ship right up to the upper deck.

The subdivision of the lower part of the ship into small watertight compartments has been carried as far as appears possible. The double bottom is split up into a large number of cellular spaces, and the hold is divided by a longitudinal middle line bulkhead, and numerous transverse bulkheads. The boilers are contained in four separate watertight compartments of the hold, three being placed in each, and each pair of engines is also contained in a separate watertight compartment. The advantage of such an arrangement is sufficiently obvious, in view of the possibility of one of the boilers or engine rooms being bilged by a blow from a ram or torpedo. The double bottom is arranged so as to include the coal bunkers, as in the *Derwent* and *Inflexible*. By these means buoyancy is gained if one of the compartments is opened up to the sea, as the water can only find its way among the interstices of the coal, and a large quantity is thus kept out of the ship.

The cabins and accommodations for the crew will all be below the

armored deck, and will be ventilated artificially, as in the ironclad monitors. They will be lighted throughout by the electric light, which is already being fitted in several ironclads, and is likely to become extensively used for this purpose. An electric light will also be fixed in the lookout on the polemast, for reconnoitering and signaling purposes.

The most remarkable and novel feature in the ship yet remains to be described. The bottom plating on each side, instead of ending in a keel or flat keel plate at the middle line, is formed into a recess; so that in place of a keel there is a rectangular groove, 1 foot 8 inches wide and 3 feet deep, taken out of the bottom of the ship. This groove or recess is intended to be filled with cast iron ballast up to a weight of 300 tons. The ballast will be cast in several lengths, and will be so attached to the ship that, in the event of a compartment becoming bilged and its being desirable to lighten the ship, the ballast can be let go and dropped from any part, as may be required. The draught and trim may thus be regulated to a certain limited extent should the vessel be damaged in action. This is a point that will probably be discussed among engineers. The object of carrying the ballast seems to be to keep the ship down in the water, and prevent the deck from becoming too much exposed when the ship is uninjured; but should she become still further immersed from any cause, the dropping of the ballast will somewhat relieve and lighten her. The utmost effect of the ballast will be to enable the vessel to float 12 inches to 14 inches lighter when it is dropped than she would do before. In other words, although her armored deck is only 4 feet 6 inches above the water, and this height only is exposed to the enemy's fire, the surplus buoyancy, on account of the ballast, will be the same as though the armored deck stood 5 feet 6 inches or 5 feet 8 inches above the water line.

It will be obvious that this quantity of ballast, amounting to about one-ninth of the whole weight of the ship, cannot be carried about for nothing. It adds to the work the engines have to do, and a greater expenditure of engine power for a given speed will be required to enable the ship to drag the ballast about with her. The additional engine power that will be required to drive the *Polyphemus* at full speed, after adding the ballast, will necessitate an increased coal consumption of 9 to 10 per cent., and a corresponding reduction in coal endurance. It will hardly be considered necessary to carry about all

this dead weight in time of peace, and it will be a question for practical consideration whether the carrying of it about in time of war at a cost of reduction in speed, or in coal endurance—and this in a ship whose coal supply is very small for her power—will be compensated for by the armored deck being 4 feet 6 inches out of water, instead of 5 feet 6 inches.

The *Polyphemus* is more or less of an experimental character, and the building of future ships possessing some or all of her characteristics, will depend upon the results of her trials. She is not likely to create a great revolution in war shipbuilding, or to show that guns are unnecessary in a fleet. Indeed, it must be evident that there are many operations, such as the bombardment of fortifications, which could only be carried out by ships armed with guns. The question respecting the *Polyphemus* is not whether such vessels as she are to supersede gun vessels, but whether she may not serve the more humble, though very useful, purpose of starting a type of war ships that will be valuable auxiliaries in action. Mr. Ward Hunt, on the occasion before referred to, spoke of her as follows :

"This vessel, must of course, to a certain extent, be regarded as an experiment, and, even supposing it to be a success, I could not propose it to the House as being likely to supersede all other kinds of fighting ships, but only as a useful adjunct to a fleet in case of war. Probably it would not be desirable that she should be kept at sea for a long period at a time, but I venture to think she will prove a very formidable weapon, and, if she should be a success, she may perhaps be regarded as a sort of rival to those monster ships with tremendous armor that we hear spoken of as likely to be built in some foreign ports."

The *Polyphemus* was commenced in September, 1878, and is already far advanced, being entirely framed and plated, except at the extreme ends. Great progress is being made with her, and she could be got ready for launching in a very few months.—*London Times*.

Absorption of Hydrogen by Nickel.—M. Raoult has shown that porous nickel absorbs hydrogen when it is employed as the magnetic electrode in the decomposition of acidulated water. —*Proc. Soc. Franc. de Physique*.

NEW SUBMARINE CABLES.

After a period of stagnation extending over five years, there is again a revival of submarine cable enterprise; and cable electricians, who have been for that time deprived of their legitimate occupation, are now experiencing brighter prospects. There are no less than four distinct cables in course of being manufactured or laid; and others are projected. Last year the Eastern Telegraph Company completed the duplication of their Oriental lines from England to Bombay, and the Eastern Extension Telegraph Company, which prolongs the Eastern Company's system to Australia *via* Madras, Penang on the Malay Peninsula, and the East Indian Islands, are at present engaged in duplicating their lines also, a work which has been somewhat delayed, however, by their giving up 1400 miles of ready-made cable to form a portion of the cable to the Cape. The latter important line of communication is, of course, the chief cable operation now in hand, and we regret to see that there was some delay in the furtherance of the work, for the steamship *Kangaroo*, belonging to the Telegraph Construction and Maintenance Company, who are the contractors, although she arrived at Durban on May 21, 1879, with the Natal to Zanzibar section on board, had not begun to lay her cargo until June 17th. For some unaccountable reason a valuable month was lost by this cable steamer, although the need for the cable is, or at least was, so urgent. It is to be hoped that the difficulties in the way, whether due to bad weather or faults in the core, or to the rumored refusal of a subsidy by the colony of Natal, on the ground that the terminus ought to be within the Natal borders, have by this time been smoothed away, and that the line is now laid as far as Zanzibar. The second section is on its way out in the steamship *Seine*, and the steamship *Calabria* carried the remainder.

The agreement between the Eastern Telegraph Company and the government requires that the entire cable shall be capable of transmitting fourteen words a minute, and that the company shall, save in cases of *force majeure*, have the portion of the cable between Durban and Zanzibar opened for traffic by July 31st, and the entire line by the last day of 1879. The company agrees to keep a repairing ship, properly equipped, in the Red Sea or Indian Ocean for maintaining

the line. All government messages, whether imperial or colonial, are to have priority to all other traffic, at one-half the rate charged to the general public. The public rate is not to exceed 5s. per word between Durban and Aden; 4s. per word between Zanzibar and Aden; and between Aden and London, by the Eastern Telegraph Company's lines, the sum of 3s. 9d. per word. The total charge for a message from Durban to London must not therefore exceed 12s. 9d. per word. Her Majesty's Treasury may nominate an official director on the boards of the companies owning and working the line, to whom every information must at all times be afforded. On the completion of the line between Natal and Zanzibar, the treasury agrees to pay, during a term of twenty years, an annual subsidy of 17,500*l.*, and a like sum on completion of the line between Zanzibar and Aden, provided always that the line is kept in good working order. In case of war, rebellion or other emergency, the Imperial Government or the government of any British colony or possession, duly authorized by Her Majesty's Government so to do, may take possession of the cables, stations, offices and apparatus on the line, and keep possession of them for as long as they may think fit. For this privilege the government agrees to make a reasonable compensation to the company. The last clause provides that the agreement shall not be binding until it has been approved by a vote of the House of Commons. It is, we think, a wise foresight on the part of the government to arrange for taking possession of the lines themselves if need be, and the day is perhaps not far distant when not only the Cape cable but also the Indian cables of the Eastern Telegraph Company may become the property of the nation.

The second great cable enterprise, now in progress, is the Pouyer-Quertier scheme for two Atlantic cables from Brest to New York. This project was ostensibly put forth as designed to gratify the *amour propre* of the French people, who wished to have Atlantic cables of their own. But the offer of the Anglo-American Company to sell or lease them a cable was declined and the original plan adhered to. It is probable that the ultimate aim of the new company is to compete with the existing Atlantic cables for English as well as Continental traffic, a supposition which is borne out by the fact that the Scilly Islands off the coast of Cornwall have been chosen as an intermediate landing point for the cable. The new cables are being made by Messrs. Siemens Brothers at their Charlton works, and the steamship *Faraday*,

which laid the direct United States cable, has already submerged the Brest to Scilly section of the first line.

Within the limits of Europe itself a short cable made by Mr. Henley for the Russian Government was recently laid across the Caspian Sea, and there is now in process of manufacture a new German-Norwegian cable, intended to connect Scandinavia direct with Germany. Hitherto the latter power has been obliged to send all her telegrams to Norway through Denmark and Sweden, a course which was irksome to her, owing to the uneasy political relations which have for a long time existed between her and Denmark. The agreement entered into between the representatives of the German Empire and the governments of Norway and Sweden stipulates that Germany shall lay the new cable at her own cost. It is to be a three-wired line, and will be laid from Romoe, an island off the west coast of Schleswig and the Norwegian peninsula, at a point near Arendal. At the latter place it will be connected to the whole Scandinavian telegraph system. The cable is estimated to cost 95,000*l.* and will belong to Germany, who will also repair it. All telegrams from Norway to Germany are to pass through the new line, and also three-fifths of the Norwegian traffic with other countries (excepting Russia, England and Denmark), unless the new route should prove more expensive than the old ones. It is obvious that this arrangement will materially reduce the inland telegraph revenue of Denmark, for hitherto all the German-Norwegian traffic has passed through that country. The new cable is, we believe, being manufactured by Messrs. Siemens and Halske, of Berlin, and it is expected to be laid some time in August.

Besides these actual performances, there are at least two projects for new submarine cables afloat; one by the American Cable Company to lay a line from New York to Flores, an island of the Azores, with one connecting line from Flores to France, England and Holland, and another from Flores to Fayal (Azores), San Miguel and Lisbon. These will comprise 7300 miles of line, if they are ever executed. The other scheme is for the long-talked-of Pacific Ocean cable from some point on the western coast of the United States to the Sandwich Islands and thence to Japan and China. Mr. Cyrus W. Field, the cable veteran of Atlantic fame, is the chief promoter of this undertaking, and he was in England for the purpose of investigating the subject of making and laying the cable in question. He holds, it appears, an exclusive concession from the government of the Sandwich

Islands for such a cable; a fact which was first announced at the recent Cable Jubilee or celebration of the twenty-fifth anniversary of the organization of the first Atlantic Cable Company. Similar concessions have yet to be obtained from China and Japan, but as the Celestials are now awake to the advantages of the telegraph, it is expected that these will be obtained without difficulty. A company will be formed to carry out this work and Mr. Field has, we understand, agreed to contribute \$100,000 as a subscription to the capital stock. The establishment of this cable would complete the telegraphic circuit of the world, and we can only hope that Mr. Field will be as successful in carrying the electric wire across the Pacific Ocean as he was in spanning the Atlantic.—*Engineering*.

RECTANGULAR BORING MACHINE.

At one of the recent meetings of the Franklin Institute Dr. Robert Grimshaw exhibited a sample of the work done by J. Hall's rectangular hole boring machine. As this mechanical paradox attracted considerable attention at the Paris Exhibition, the readers of the JOURNAL will be interested in a brief explanation of it.

The drill has for section an equilateral triangle. The tool-holder of a special shape, having a screw at the upper portion, then a rectangular section; then a round section of a given diameter; then another section of the same shape, but of a greater diameter. There is a hollow rectangular sleeve, somewhat larger and narrower than the rectangular section. A slight horizontal and vertical movement can be thus obtained. This sleeve varies in size and in amount of play according to the work to be done. When the tool is in position it is guided by a steel plate, which has a hole corresponding to the one we wish to bore.

In turning, the tool occupies various positions, the cutting portion following the exterior contour of the rectangular guiding plate. If a pressure is exerted upon the tool, the boring will commence producing, as desired, a rectangular hole. If any portion of the tool be considered during its rotation, it will be found that the loci of the same represent most interesting curves of the third and fourth orders.

PETROLEUM AS FUEL.

A method of using petroleum as fuel for steam boilers has been recently tried at Pittsburg with, it is said, complete success, and as oil can be had anywhere in the region of the wells for about 70 cents a barrel, the company who hold the patent believe that the invention will be readily taken up, especially by the owners of steamboats. It resembles in its principal features many of the forms we have previously described—air, steam and oil-spray being injected into a suitable fire-box. The spray is said to be immediately converted into inflammable gas, becoming a pure, bright, powerful flame, devoid of smoke and producing intense heat. To accomplish this result extremely simple machinery is used. A small hole is drilled into the iron front of the fire-box, and into this passes a tube which branches as it leaves this point into two pipes. One of these connects with the boiler itself, and the other with the receptacle containing crude oil. At the junction of these pipes there is an aperture for the admission of atmospheric air. Valves of peculiar construction regulate the quantity of steam or oil admitted to the furnace. This is all the machinery required, but its operation, according to the *Pittsburg Telegraph*, is wonderfully complete and remarkably successful. The little steamer *Billy Collins* was selected by Mr. Campbell for the test and was fired up at 9 A. M. A preliminary blaze of wood under the boiler raised the small quantity of steam necessary to start the burner into operation. The oil valve was opened a trifle, the steam valve ditto. The petroleum trickled into the feed pipe, was caught up by the steam, and both plunged into the depths of the fire-box, a mass of many-tongued, roaring, brilliant flame. As the pressure of steam increased, this flame grew in fury and intense heat, roaring through the entire length of the boiler with a sound like the coming of a thunderstorm. The needle of the steam gauge climbed rapidly up the dial, and in twenty minutes the safety valve blew off at 120 pounds pressure. It was a remarkable sight. Here was a boat puffing through the water with no sign of smoke from her chimneys, no speck of soot in flues or fire-box, no fireman, no opening of furnace doors, no dirt, no coal going in, and no clinkers or ashes to be seen anywhere. A turn of the hand regulated the terrible flame that seemed trying to overpower the limits

of the furnace, and another turn of the hand brought the fire down to a quiet little flame, a foot or two long. During the forenoon occupied by the test, about 20 gallons of crude oil were consumed, and Mr. Campbell's estimate was, that with oil one dollar per barrel, this fuel was equivalent to coal at six cents [quantity not stated] in heat-producing value, other things being equal. But other things are not equal by any means, and everything is in favor of oil as against coal. The labor and expense of "firing up" is dispensed with, and the engineer can regulate the flame as he does the steam in his engines. The danger from sparks and flying cinders is entirely done away with. The space occupied by oil, as compared to an equal value of coal, is very much less, and this much is gained for cargo. Further, the wear and tear upon boilers, grate bars, etc., is infinitely less, and, it seems scarcely necessary to add, the comfort of passengers is greatly enhanced by the absolute freedom from dirt of all kinds. To the Western boatman this method of steam-producing is full of interest. "Coal is coal" on Western rivers. Here is a fuel that seems provided by nature especially for use on craft where every atom of carrying space is valuable. To ocean-going steamers this device must prove of extraordinary interest. A tank of oil situated at a remote end of the ship would hold fuel sufficient for a double trip, and supplant the great coal bunkers with their attendant dirt. Space prevents even a glance at the possibilities of this burner on the ocean. To railroad men this burner is full of promise also. A locomotive boiler, with its many tubes, would be pierced in every part with this wonderful oil flame, and the benefits arising from the entire absence of sparks, cinders and smoke are simply incalculable.

Taming Horses by Electricity.—The Paris Omnibus Company employs a full electric current as an effective check upon all restive horses. The current is excited by a small Clarke induction machine, the wires communicating with the bit through the reins. In case of any resistance or viciousness on the part of the horse, the driver simply presses a button, and the moment the current is felt the will of the animal seems to be completely annihilated, so that he submits at once. The effect seems to be a simple numbness and uneasiness, rather than an actual pain, and the method is generally regarded as much more humane than whipping, curb-bits and other common appliances.

—*La Nature.*

C.

ARTIFICIAL DIAMONDS.

The production and manufacture of imitation precious stones, always considerable, has been rapidly increasing in France of late years, and at the present time, owing to the perfection at which the art has arrived, the demand greatly exceeds the supply. The chief seat of the manufacture is supposed to be Paris, but this is a popular error. The dealers carry on business in that city, but the artificial stones are manufactured in the mountains of the Jura, Franche-Comté, the communes of St. Claude, Septmoncel, la Meure, les Molunes, and the surrounding districts. The inhabitants, men, women and children, are entirely engaged in the production of these stones, and have been so for generations past. They particularly excel in the cutting of artificial diamonds, the process of which we shall explain in detail in a future article. At the present time this species of industry has developed into a great resource for the inhabitants of the above districts, and they positively neglect the cultivation of the land in its favor. Certain of them undertake the cutting of real stones, but in this, as a whole, they cannot approach the careful workmanship and execution of the Paris lapidaries.

At the present day a special composition possessing a considerable refractive power serves exclusively as a base for artificial diamonds and other precious stones. This product is called *strass*. It differs from glass by the presence of about fifty per cent. of oxide of lead comprised in its elements. The name is derived from that of a workman named Strass, who, in the last century (about 1772), first directed attention to the composition, and is credited with being the inventor.

At the present time strass consists of the following:

Silica,	.	.	.	.	38·2
Oxide of lead,	.	.	.	.	50·0
Potash,	.	.	.	.	7·8
Alumina, borax, arsenious acid,	.	.	.	.	traces.

The ingredients and substances composing modern strass are doubtless the same as those employed in the Middle Ages, and it is probable that their proportions differ but slightly. But modern chemistry provides the manufacturers of our day with products of perfect purity,

and the *modus operandi* has become greatly simplified. The procedure of the early makers was prodigiously complicated. They were nevertheless aware of the fact, confirmed by modern experience, that the longer the fusion was continued the more beautiful the strass became. When the substance is produced perfectly pure it serves to imitate all precious stones. It is remelted and intimately incorporated with substances with metallic bases, generally oxides, which by their combination with the elements of the strass communicate to it divers colors. Imitation sapphires are produced by 1000 parts of strass and 25 of oxide of cobalt. Emeralds, by 1000 parts of strass, 8 of oxide of copper, and 0.2 of oxide of chromium. *Diamonds*, being colorless, pure strass alone is employed, cut in the form of a brilliant or rose.

Artificial diamonds composed of mere strass alone were however at the best most unsatisfactory imitations. They were soft, white and glassy, and quickly thrown aside by purchasers as failures. Quite recently, however, one of the descendants of the Franche-Comté lapidaries, after many years of patient investigation, has brought about a revolution in the manufacture of imitation diamonds. He substitutes a preparation of gold for the oxide of lead in the composition of the strass, and further, the stones when cut are subjected to a chemical process by which the refractive power is made equal to that of real diamonds of the purest water. These perfect stones attracted great attention, and were much commented upon in the Paris Exhibition, where they were exposed side by side and in the same cases with real diamonds of great price. They are now being introduced to the English public under the name of *diamants brillants*. The samples which have been submitted to our inspection are certainly far nearer in their resemblance to real stones than anything of the kind which has previously come under our notice.—*English Mechanic*.

HEATING BY RADIATION.

By LEWIS W. LEEDS.

That the earth should be surrounded by and be driven through a space of intense cold, and that all the sensation we term heat should come through millions of miles of this intense cold before reaching us, ought to give us some hints of the natural conditions under which

our existence becomes possible. The whole warmth upon the surface of the earth is received by radiation from the sun. The air is warmed by coming in contact with the warmed earth. The air warmed by this contact with the heated earth rises, and the colder air from above tumbles down to take its place. This forms the great natural ventilation or circulation of air over the surface of the earth which sustains all life.

We should endeavor to imitate this in our artificial arrangements for heating buildings. As all solid objects at the surface of the earth are warmer, on the average, than the air, our bodies are made to conform to that condition. They are, therefore, much better sustained while inhaling the natural cold air than when inhaling warmed air.

The idea of attempting to warm our buildings by overheating the fresh air supply has been a most unfortunate one for the American people. It is a very unnatural one, and it is impossible to make our systems conform to it. It has been adhered to and pushed with characteristic American perseverance, but the third and fourth generations submitted to such premature stewing seem no fonder of it than their great-grandfathers. They only become less in stature and weaker in mind, and if continuously fed on such air would probably act much like the Irishman's horses, just as they had become able to endure such worthless, straw-like stuff, they would die.

For healthfulness the open fire most nearly imitates the radiant heat of the sun. The air, warmed by immediate contact with the fire, is carried up the chimney. It is not thrown into the room to be breathed.

As the radiation from the fire passes through the pure air without warming that air, it follows that the rays of heat are thrown across the room to the opposite walls and partially warms them, and warms any persons in the immediate range of that radiation. It follows, therefore, that the persons in a room may be comfortably warmed by the direct rays of an open fire or other hot body while being surrounded with and inhaling cold invigorating air. This is much more wholesome and more agreeable to our system, because more natural, than when surrounded by that artificial condition produced by all our warm air contrivances, when the air is hotter than the solid objects in the room. All these air-warming contrivances which we have been introducing so extensively are unnatural and incorrect, and the sooner we abandon them and adopt the natural system of warming by radiation, as is done by the sun, the better it will be for the health, strength and prosperity of the nation.—*Plumber and Sanitary Engineer.*

Potential Energy of Liquid Surfaces.—In 1876, G. Van der Mensbrugghe demonstrated the two following propositions:

1. If the upper free layer of a liquid mass undergoes an expansion, it becomes cooler; if, on the contrary, it contracts, it becomes warmer.

2. In each case there are developed in the mass thermo-electric currents, with intensities inversely proportioned to the mass, and directly proportioned to the surface variations.

He applied these propositions to the explanation of the movements on the surfaces of soap-bubbles, the alternating movements of liquid layers on other liquids, the occasional extraordinary production of heat in a solid when moistened by a liquid, the thermo-electric currents developed by variations of extent in the surface of separation between two liquids, the enormous electric discharges in storms, the maintenance in a liquid state of the little drops which form clouds and mists in a freezing atmosphere, the exceptional phenomena presented by some alloys near their limits of greatest density, the intense heat which is required to detach a volatile liquid from a porous surface, the phenomena of ebullition observed in Donny's classical experiments, Hansen's relation between meteorological perturbations and magnetic variations, the movements of bubbles of air in levels and vapor-bubbles in the cavities of minerals, and Savart's phenomena in liquid sheets. In a recent paper he has extended the application of his formulas to the loss of heat in a jet of vapor, the increasing energy of waves, the formation of bars at the mouths of rivers, and the motion of the Gulf Stream. His explanations are all very ingenious, and many of them are confirmed by satisfactory experiments.—*Bull. de l'Acad. Roy. de Belgique*.
C.

SCIENTIFIC SPECIALTIES.

MORPHOLOGISCHES JAHRBUCH, v. 5, part 1. A. Rauber, on the occurrence of budding among the vertebrata.

JOURNAL DE PHYSIQUE, June. Cornu, spectroscopy for ultra-violet. Crova, spectrometry of high temperatures. H. Becquerel, magnetic rotatory power of gases. Bichat, do. of liquids and their vapors.

ANTHROPOLOGICAL INSTITUTE, London, June 24. W. H. Flower, osteology of the Andamar Islanders.

PHYSICAL SOCIETY, June 21. Unwin, friction of fluids on solid substances against which they rub. June 28. Adams, new measuring polariscope. Conroy, distribution of heat in the spectrum.

NATURE, July 17. Hollway, use of sulphides as fuel for rapid oxidation. July 24. Galton, results of experiments on friction at high velocities, showing effect of brakes on railway trains. Moebius, on the Eozöon question. July 31. Carpenter, on the Eozöon. Ferrier, review of Calderwood on brain and mind.

ROYAL SOCIETY, June 19. Roberts, new tide-prediction.

ACCADEMIA DEI LINCEI, June 1. Tommaso-Crudelis and Kubs, nature of the specific agent which produces fevers from malaria. Villari, thermic and galvanometric laws of electric sparks from condensers.

QUARTERLY JOURNAL OF MICROSCOPICAL SCIENCE, July. Lewis, microphytes in blood, and their relation to disease.

JOURNAL OF ANATOMY AND PHYSIOLOGY, July. Fleming, physiology of the Turkish bath, and effects of hot dry air upon man. Hamilton, on the process of healing.

RIVISTA SCIENTIFICO-INDUSTRIALE, Nos. 11—13. Ferrini, electric conducting power of carbons. Palazi, constitution of fogs and clouds. Roster, new method to determine the melting point of organic substances.

VIENNA ACADEMY, May 15. Lippich, electro-magnetic rotation of the plane of polarization of light in air.

PHILOSOPHICAL MAGAZINE, August. Rowland, on Ayrton and Perry's new theory of Earth's magnetism. Smyth, spectroscopy of C and carbo-hydrogen. Preston, consistency of cyclical changes with the tendency to temperature-equilibrium.

AMER. JOUR. OF SCIENCE AND ARTS, August. Upham, terminal moraines of the N. A. ice-sheet. Cutter, microphotography with Tolles' $\frac{1}{75}$ inch objective. Kimball, magnetic strains in iron. Hilliard, loess of the Mississippi valley and the Aertian hypothesis. Peirce, on Faye's method of swinging pendulums for the determination of gravity. Hodges, on the size of molecules.

AMERICAN NATURALIST, August. Gatschet, adjectives of color in Indian languages. Upham, formation of Cape Cod.

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ON THE STRENGTH OF AMERICAN TIMBER.*

[An Experimental Investigation made in the Mechanical Laboratory of the Stevens Institute of Technology.]

By Prof. R. H. THURSTON.

INTRODUCTORY.—One of the earliest investigations planned by the writer when organizing the Mechanical Laboratory of the Stevens Institute of Technology was that here described. Nearly all our knowledge of the strength of timber was derived from foreign sources and was of limited extent, and authorities were somewhat conflicting in statement.† It was evident that more work in that department of research was required, and that experiments on the strength of American woods were demanded not only by engineers and architects in the United States, but by members of the profession in Europe, where some American timber—especially our soft pines—is used.

The experiments here described are too few in number, and cover too limited a portion of this field to claim attention as really authori-

* A paper read at the Saratoga meeting of the American Association for Advancement of Science, August, 1879.

† Compare Barlow and Tredgold with Laslett. Barlow on the Strength and Stress of Timber, London, 1826; Tredgold's Elementary Principles of Carpentry, London, 1870. Laslett on Timber and Timber Trees, London, 1875.

tative and satisfactorily complete ; they will, however, have some value, and may be taken as an initial portion of a complete study of American woods which, it is hoped, may hereafter be made.

The writer desires to express his obligations to the Secretary of the Navy, to the Chief of the Naval Bureau of Construction of the Navy Department and to the Naval Constructor of the Brooklyn Navy Yard for a kindly interest taken by them in the work, and particularly for the important assistance rendered by them in carrying it out.

It seemed eminently desirable that the woods examined and experimented upon should be of the kinds used most generally in construction ; that the specimens should be of sound, good stock, and that the test-pieces should be carefully and accurately made to standard size and shape. As the best means of securing these desiderata, the Secretary of the Navy and the Chief of Bureau were requested to furnish test-pieces of the form and size standard in the Mechanical Laboratory of the Stevens Institute of Technology. The favor was cheerfully granted, and the Naval Constructor, on receipt of orders from the Navy Department, prepared the required specimens at the Brooklyn Navy Yard, at the earliest practicable date, taking a personal interest in securing the desired quality of material and accuracy of workmanship. The samples thus furnished may be regarded as well representing those American woods which are here treated of.

The samples furnished were of white and yellow (Georgia) pine, locust, black walnut, white ash, white oak and of live oak.

The characteristics of good pine timber are the following :

It has a close grain and its slow growth should be evidenced by the thinness of the annual rings, which should not exceed a tenth of an inch. The trunk, and consequently its rings, should be symmetrical.

The best timber is charged with resin, which preserves it from decay, and gives it strength and elasticity ; its presence is indicated by strong odor. The color of the wood should be a clear tint of yellow and red, alternating, and the texture as well as the colors should be very uniform.

The working of the timber gives a reliable indication of its quality. It should offer considerable resistance to splitting along the grain, it should be strong and free from wooliness, and the cut of the saw, and of the plane or chisel, should leave smooth surfaces. The shavings and chips should be strong and elastic, and the former capable of being twisted about the finger without breaking.

White pine (*Pinus strobus*) is a native of North America, and takes its name from the color of its wood. It grows in all kinds of soil. The best timber is found in cool, damp situations, in the forests of the Northern United States and Canada, between the forty-third and forty-seventh parallels of north latitude. It really flourishes well as far south as Virginia. It grows to great size, reaching a height of upwards of 200 feet, with a diameter of 10 feet at the height of a man's shoulder from the ground. It is the tallest tree in our forests. It sometimes reaches the age of 350 years. Single logs have been cut 36 inches square and 60 feet long.

Its wood is yellowish-white in color, light in weight, rather soft, free from knots, straight grained, and is very easily cut. It is durable only in dry air. It contains very little resin; its leaves are very slender; its cones are very nearly cylindrical and 4 or 5 inches long. Its leaves are pale green in color. Its specific gravity is about 0.7 green and 0.5 seasoned. It is used for light carpenters' and joiners' work, and is remarkably well adapted to pattern makers' use. It has been employed to a considerable extent in building wooden bridges. It is not a very strong wood, and swells or shrinks seriously when the hygrometric state of the atmosphere changes considerably. For many purposes its softness is a serious objection.

The American Yellow Pine, "*Spruce Pine*," or *short-leaved Pine* (*Pinus mitis*, *Pinus variabilis*), is found throughout the country, in dry sandy soils, from New England to Georgia. It is much used in carpentry, and for framing and flooring, and in ship building; it is also used for the masts and yards of large vessels. The trunk is straight and slender. The heart wood is fine grained, moderately resinous, strong and durable. The sap wood is poor in quality, and decays rapidly. Its cones are small; its leaves are in groups of threes, and from 3 to 5 inches long. It attains a height of 60 feet and a diameter of 18 inches.

The Southern Pine, "*Long-leaved Pine*" (*Pinus Australis*, *Pinus palustris*), is distributed along the Atlantic coast from Maryland southward, on sandy, light soil. It is probably the most generally useful of our woods, and immense quantities are brought into market.

Its name is sometimes confused with that of the *pitch pine*, and both kinds of wood are known in the Eastern States as *hard pine*.

Both kinds are extensively used by Atlantic ship builders for plank-ing, beams, etc., but seldom for any part of the frame.

The yellow pine sometimes attains a height of 150 feet and a diameter of 4 feet; but the pitch pine seldom exceeds two-thirds this size. The former is principally obtained from the States of Virginia, North Carolina and Georgia, while the latter is abundant in all the Atlantic States south of Chesapeake Bay. The yellow pine required for navy yard use is described as long-leaved, fine-grained Southern yellow pine. Its leaves are light green, 8 to 11 inches long, and rigid; they are dark green in color. The cones are 6 to 8 inches long.

It has but little sap wood, and the heart wood is of very uniform quality, its resinous matter being very regularly distributed. Its grain is fine and close, and it has greater strength, durability and hardness than any other species of pine.

Though not as tough and elastic as white oak, the yellow pine, especially that from Georgia, successfully rivals it in stiffness. If a beam of each kind of timber, equal in dimensions, be suspended by the ends, the oak beam will depart most from its "mould," but will break under about the same load. In dry situations the pine is extremely durable, and where the properties of lightness and solidity are required in combination it is to be preferred to oak. Experiments upon the shrinkage of various woods by Mr. James Jarvis, at the U. S. Navy Yard, Norfolk, Va., indicate that yellow pine should be cut in summer.

The Locust or common Acacia (Robinia pseudo-acacia) is a flowering tree, found in the mountainous and hilly portions of the country from Canada to the Southern States.

It grows rapidly and reaches a height of 70 feet with a diameter of 4 feet, but is usually considered full grown if 40 feet high and a foot in diameter. It is a fine ornamental tree.

The wood has a peculiar greenish-yellow color, resembling boxwood slightly. The structure is alternately very compact and quite porous. Its annual rings are thus very distinctly marked.

It exhibits no medullary rays, and the wood has neither taste nor odor. When of good quality it is difficult to cut and work. It is a very valuable timber.

It is especially valued for fence posts and rails, or boarding, but is seldom found of sufficient size and in quantity sufficient to be used in the latter form. It turns well in the lathe and has great torsional strength and resilience, excelling all other common woods in this quality.

The Ash (Fraxinus excelsior) of Europe and the White Ash (Frax-

inus Americana) of America are also valuable timber trees. Their woods have many useful applications. Ash is quite similar in color to oak and in texture to chestnut. It is straight-grained, remarkably tough and elastic, excelling all other common woods, and answers admirably for handspikes, heavy oars, ship blocks, tool handles, the wooden portions and framing of machinery, and for wheel carriages and agricultural implements. It is durable under cover, but decays rapidly if exposed to the weather. The tree grows to a height of 60 feet, and acquires a diameter of 20 inches in rich, moist, loamy soil. It has no observable sap wood.

The *Black Walnut* (*Juglans nigra*) is found throughout our Middle and Western States, and as far south as the Gulf of Mexico. The tree presents a fine appearance, attains considerable size, and yields a much-prized timber.

The wood varies considerably in quality. It is of a brown color, approaching red in some specimens, and of a dark chocolate color in others. The sap wood is frequently quite light in color. The best wood has a fine grain and a dense structure, although usually excelled in both particulars by good mahogany.

It is strong, durable and easily worked. It is more generally used in the United States for furniture and for ornamental purposes than any other wood, and immense quantities of it are annually worked up. It is nearly as strong as mahogany and is tougher.

The *Live Oak* (*Quercus vivens*) is one of the best known ship-timber trees. It is evergreen and grows on the sea coast from Maryland to the Gulf of Mexico and the Mississippi, and is now so scarce and so valuable that the government has reserved all of the Florida live oak forests for naval purposes.

This timber is used almost exclusively for the purposes of ship building. It is heavy, compact, fine-grained, yellowish in color, and is the strongest and most durable of all American woods.*

The tree grows to a height of 60 feet, and to a diameter of 4 feet, but is usually 40 or 45 feet high and 12 to 18 inches in diameter. The capillary vessels of the heart wood are filled with a gummy substance; unlike other varieties of oak in our country, it is free from acid.

Live oak is not well adapted to the reception of spike fastenings, as

* The writer possesses a live oak cane taken in 1865 from the keel of the frigate *United States*, a naval vessel built very early in the present century. It is as perfectly sound, apparently, as when first cut.

the grain refuses to receive the point in the cutting direction, and permits splitting of the wood. There is no difficulty, however, in fastening with bolts and tree-nails. The sap wood is whitish in color, and is free from the glutinous matter found in the dense heart wood. Live oak, if exposed long in the open air, in the rays of the sun, or to winter winds, will check badly. It does not require many months of air-seasoning, however, to fit it for its ordinary uses. It is the most costly ship timber in the market.

The White Oak (Quercus alba) is a more common and a very valuable variety, and is in extensive use, especially for ship building, for which its trunk furnishes the heavier timber, and its large roots and branches yield the "compass timber." It is used for water-wheel shafts and other millwrights' work. The bark is of great value for tanning.

This tree is found from Canada to the Carolinas, and is most abundant in the Middle States, forming large forests west of the Alleghany range of mountains. It reaches a height of 80 feet and more, and its trunk is sometimes 6 or 7 feet in diameter. It is one of the few trees which retain any of their leaves throughout the winter. The leaf is deeply indented, long and narrow. Its bark is of a light grayish-white color, giving it its name; its wood is light straw colored, with a tinge of red, and is very tough, strong, durable, elastic and pliable, with strong lateral cohesion. It is very liable to shrink, warp and crack in seasoning, and is therefore of little value for boards. It is used for artillery carriages and makes very good steps for the lower ends of turbine water-wheel shafts. The shrinkage amounts to about $\frac{1}{32}$.

The wood of trees sixty to one hundred years of age is much tougher, particularly on high lands, than that of older trees. The wood from the roots makes beautiful furniture. The cost and the difficulty of working it preclude its extensive use. No certain data exist for comparing the properties of white oak grown in various districts, but it is generally supposed that the best timber for durability is that grown near the Atlantic seaboard or along the borders of the great lakes. Generally the strongest timber is grown on wet lands. The experiments of Jarvis prove, first, that there is ten per cent. in one year and five per cent. in four years more shrinkage in weight of the squared timber which is cut in the warm season than in that cut during the cold season; secondly, that in case of round logs, in bark, there is eight per cent. in one year and seventeen per cent. in four

years more loss by evaporation if cut in the summer season. It has a specific gravity of from 0.7 to 1.1, weighing from 44 pounds dry to 70 pounds when green per cubic foot.

THE FORM AND DIMENSIONS OF TEST-PIECES used in these experiments (see Figs. 1 to 4) were, as at first prepared, given in the accompanying figures:

FIG. 1. Tension.

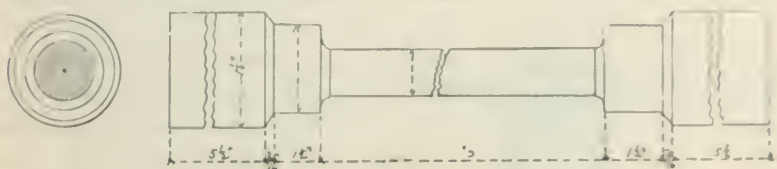


FIG. 2. Compression.

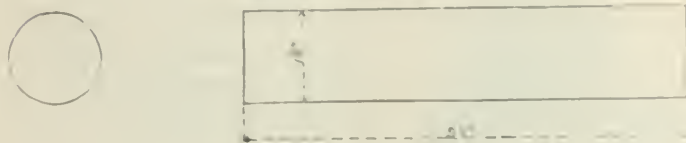


FIG. 3. Transverse.

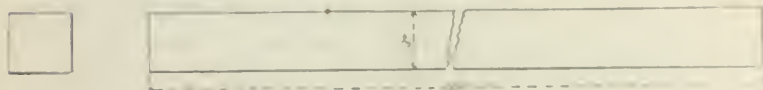


FIG. 4. Torsion.



The white pine here described was of light color and weaker than really good pine should be. Among other samples tested subsequently one bore double the load which broke this. The fact is a good illustration of the great variability observed in the strength of timber. The yellow pine was of fine quality, as were the locust and the oaks. The ash was a little too dry, but otherwise excellent.

The following table exhibits their sizes and densities:

TABLE OF DIMENSIONS AND DENSITIES OF WOODS.

NAME.	No. 1. Tension.		No. 2. Compression.		No. 3. Transverse.				No. 4. Torsion.		Weight per cubic inch in pounds.	Weight per cubic foot in pounds.
	Length.	Diameter.	Length.	Diameter.	Length.	Breadth.	Depth.	Distance between supports.	Length.	Diameter.		
White Pine,	in. 4	in. ·537	in. 2·25	in. 1·117	in. 60	in. 3	in. 3	in. 54	in. 1	in. ·780	·0017	29·376
Yellow Pine,	4	·532	2·25	1·102	60	3	3	54	1	·760	·0270	46·656
Locust,	4	·522	2·25	1·078	60	3	3	54	1	·656	·0330	57·024
Black Walnut,	4	·535	2·25	1·112	60	3	3	54	1	·785	·0220	38·016
White Ash.	4	·544	2·25	1·104	60	3	3	54	1	·762	·0200	34·560
White Oak.	4	·481	2·25	1·117	60	3	3	54	1	·780	·0240	41·472
Live Oak,	4	·497	2·25	1·117	60	3	3	54	1	·656	·0390	67·392

THE TESTING MACHINES used in this work were the standard machines of the Mechanical Laboratory of the Stevens Institute of Technology. The tension and compression machine is of a peculiar design, which has never been reproduced, and which was supplied to the writer by Messrs. Riehle Brothers, of Philadelphia.

It consists of two strong cast iron columns, secured to a massive bed frame of the same material; above these columns is fastened a heavy cross-piece, also of cast iron, containing two sockets, in which rest the knife-edges of a large scale-beam. The upper chuck is suspended by two eye-rods from two knife-edges, $\frac{1}{2}$ inch to one side of centre of a heavy wrought iron block, which is hung by two links from two pairs of knife-edges projecting from the scale beam on opposite sides of the knife-edges of the latter and at equal distances from them, the whole making a very powerful differential beam combination. All the knife-edges are of tempered steel, and the sockets and eyes are lined with the same material, thus reducing friction to a minimum. The load is applied by means of a hydraulic press, with a fixed plunger and movable cylinder; to the latter the lower chuck is fastened by means of an adjustable staple and link. The stress to which the test-piece is subjected is measured by means of suspended weights and a sliding poise. The specimen is secured in the chucks, either by wedge-jaws or cored chucks, according to the specimen to be tested. The capacity of the machine is twenty tons. Fig. 5 exhibits the machine with the sliding poise and adjusting apparatus omitted.

The extensions were measured by means of an instrument in which

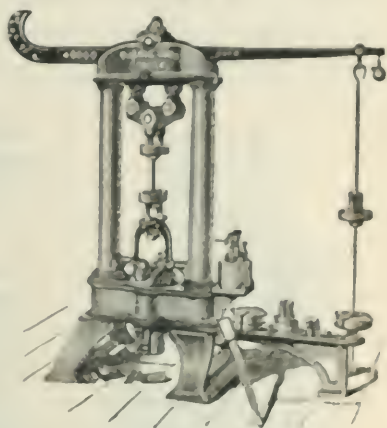
contact is indicated by an "electric contact apparatus." The instrument consists essentially of two very accurately made micrometer screws, working snugly in nuts secured in a frame which is fastened to the head of the specimen by a screw clamp. It is so shaped that the micrometer screws run parallel to and equidistant from the neck of the specimen on opposite sides. A similar frame is clamped to the lower head of the specimen, and from it project two insulated metallic points, each opposite one of the micrometer screws. Electric connection is made between the two insulated points and one pole of a voltaic cell, and also between the micrometer screws and the other pole. As soon as one of the micrometer screws is brought in contact with the opposite insulated point a current is established, which fact is immediately revealed by the stroke of an electric bell placed in the circuit. The pitch of the screws is 0.02 of an inch, and their heads are divided into 200 equal parts; hence a rotary advance of one division on the screw head produces a linear advance of one ten-thousandth (0.0001) of an inch.

A vertical scale, divided into fiftieths of an inch, is fastened to the frame of the instrument and set very close to each screw head and parallel to the axis of the screw; these serve to mark the starting point of the former and also to indicate the number of revolutions made. By means of this double instrument the extensions can be measured with great certainty and precision, and irregularities in the structure of the material, causing one side of the specimen to stretch more rapidly than the other, do not diminish the accuracy of the measurements, since half the sum of the extensions indicated by the two screws is always the true extension caused by the respective loads.*

The machine used for tests of transverse strength was designed by

* This instrument is figured and described in a report by the U.S. Board, appointed to test iron, steel and other metals, in an investigation in the Mechanical Laboratory of the Stevens Institute of Technology: "On the Properties of the Copper-tin Alloys." Washington: Government Printing Office. 1878.

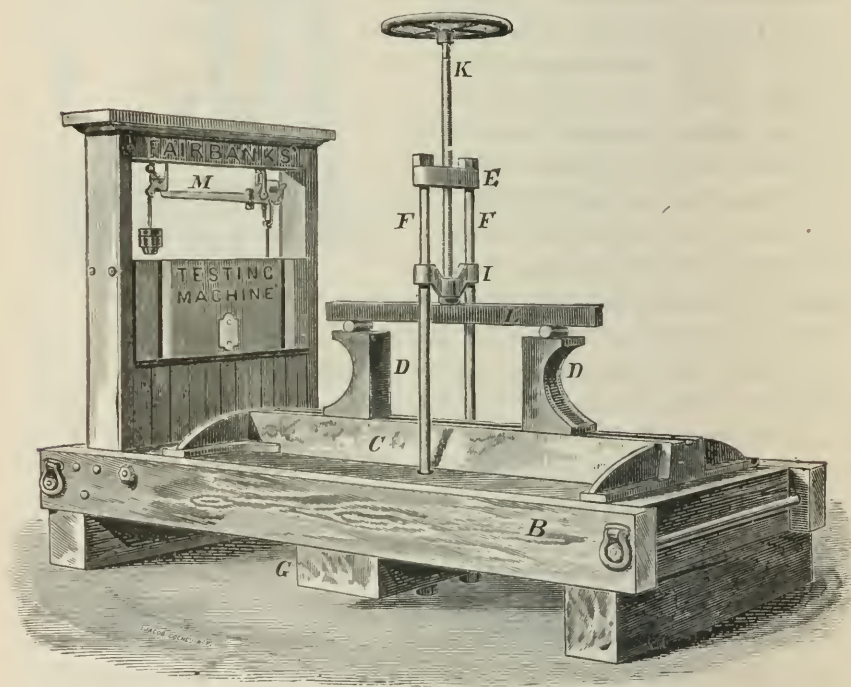
FIG. 5.



the writer, and built by Messrs. Fairbanks & Co., of St. Johnsbury, Vt. It is shown in Fig. 6.

It consists of a Fairbanks scale, on the platform of which rests a heavy cast iron beam, *C*, to which are fastened the supports, *DD*, at the required distances apart. The pressure is applied by means of the hand-wheel on the upper end of the screw, *K*, which screw passes through the nut, *E*, and terminates in the sliding cross-head, *I*. This cross head serves both as a guide and as a pressure-block. The test-piece, *L*, rests upon mandrels mounted upon the supports, *DD*, at the required distance apart. The loads are weighed in the usual manner at *M*.

FIG. 6.



The instrument for measuring deflections is not shown in the cut; it consists of an accurately cut micrometer screw of steel, having a pitch of 0.025 of an inch, working in a nut of the same material mounted in a brass frame. This instrument is supported by a rod of considerable rigidity and of sufficient length, which is secured to the beam, *C*, close to the tension rods, *FF*, in such a manner that the micrometer is

directly over the cross-head, in the same vertical plane with the test-piece, and very near and parallel with the axis of the large screw, *K*. The micrometer screw is provided with a head which is divided into 250 equal parts. Thus, a rotary motion of one division produces an advance in the direction of the axis of the micrometer screw of 0.0001 of an inch. A scale divided into fortieths of an inch is fastened to the frame of the instrument, in close proximity to the head and parallel to the axis of the screw; it serves to mark the starting point and indicates the number of revolutions made in taking a measurement with the screw.

To insure accurate readings of the deflections the principle of electric contact is also employed here.

The capacity of the testing machine is 7000 pounds.

The testing machines used for torsion-tests in the Mechanical Laboratory of the Institute are two styles of "Autographic Recording Testing Machines," devised by the writer. They had previously produced a considerable mass of records which have been, in part, presented by the writer, with interpretations, to the American Society of Civil Engineers.*

The machine employed in the earlier tests is shown in Fig. 7. Two strong wrenches, *CE*, *BD*, are carried by the frames *AA*, *A'A'*, and depend from axes which are both in the same line, but are not connected with each other. The arm, *B*, of one of their wrenches carries a weight, *D*, at its lower end. The other arm, *C*, is designed to be moved by hand in the smaller machines, and by a gear and pinion, or a worm gear, in larger forms of the apparatus. The heads of the wrenches are made as shown in Fig. 8, the recess, *M*, being fitted to take the head, on

FIG. 7.

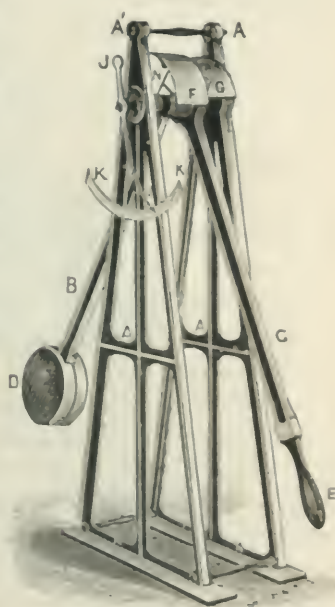
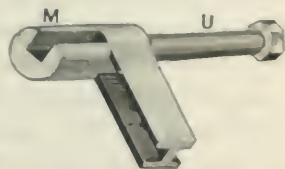


FIG. 8.



* See Trans. Amer. Soc. C. E., 1876, *et seq.*

the end of the test pieces, which is usually given the form shown in Fig. 4.

A guide curve, F , of such form that its ordinates are precisely proportional to the torsional moments exerted by the weighted arm, BD , while moving up an arc, to which the corresponding abscissas of the curve are proportional, is secured to the frame, AA' . The pencilholder is carried on this arm, BD , and as the latter is forced out of the vertical position, the pencil is pushed forward by the guide curve, its movement being thus made proportionate to the force which, transmitted through the test piece, produces deflection of the weighted arm. This guide-line is a curve of sines. The other arm, CE , carries the cylinder, G , upon which the paper receiving the record is clamped, and the pencil makes its mark on the table thus provided. This table having a motion, relatively to the pencil, which is precisely the angular relative motion of the two extremities of the tested specimen, the curve described upon the paper is always of such form that the ordinate of any point measures the amount of the distorting force at a certain instant, while its abscissa measures the distortion produced at the same instant.

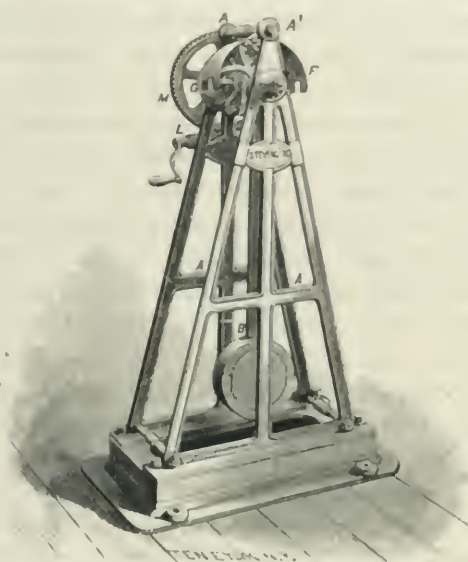
The later and improved form of machine, as now built and used in the Mechanical Laboratory of the Institute, is shown in the accompanying engraving, Fig. 9.

The frames, A, A' , are bolted to a heavy bed-plate, which secures the required stability. The worm wheel, M , engaging with the worm, I , has been substituted for the arm, CE ; the worm is set in motion by means of the crank, L , and in this manner a very slow and quite uniform motion can be obtained. Both wrenches are provided with lathe-centres directly opposite each other and in the common axis of rotation. The specimen to be tested is placed upon the lathe centres, which hold it in line while it is being secured in the jaws of the wrenches by means of steel wedges inserted from opposite sides.

Supposing a test-piece to be placed in the machine; the operator turns the crank, L , with a uniform velocity which gives a slow and a very steady motion to the wrench connected with the worm wheel, which is transmitted through the test-piece to the wrench carrying the weighted arm. The latter is moved by the force transmitted through the test-piece through an arc, which is a measure of the resistance to torsion offered by the test-piece, and is recorded simultaneously with the angle of torsion by the pencil, as explained above.

The drum carrying the record sheet is of such a diameter that the circumference is 36 inches, which, when divided into tenths, makes 360 divisions, each of which is representative of one degree.

FIG. 9.



In the machines employed in the Mechanical Laboratory of the Stevens Institute of Technology each inch of ordinate denotes 100 foot-pounds of moment to have been transmitted through the test-piece, and each inch of abscissa indicates 10 degrees of torsion. The friction of the machine is not recorded by the machine, but is added in calculating the results.

By means of this machine the metal tested is compelled to tell its own story, and to give a permanent record and graphical representation of its strength, elasticity and every other quality which is brought into play during its test, and to exhibit its characteristic peculiarities.

The machine first described was selected for use in this research and was altered to meet the special requirements of the case. The lever arm, even without the weight, giving too great a moment of resistance for some specimens of wood of the usual diameter, a counterpoise was arranged, consisting of a bar of iron bent to a rectangular shape and clamped to the lever arm below the guide curve, of such a size that,

when the lever arm was deflected, it would not interfere with the guide curve. To the top of this rectangle was fastened a vertical iron rod, to which was attached a weight by means of a set screw, so arranged that the continuation of the vertical axis of the lever arm should coincide with the vertical axis of the rod and weight.

In the diagrams produced by the machine thus modified, every inch of ordinate represents 1.058 ft.-lbs. plus the friction of the machine, which in this case is equal to .52 ft.-lbs.; the horizontal scale is the same as above, *i. e.*, one inch of abscissa equals 10 degrees of twist.

THE EXPERIMENTS were made, as stated, in the Mechanical Laboratory of the Stevens Institute of Technology. The immediate charge of the machines and the observation of results of tests was entrusted to Mr. Frank P. Jones, M. E. (Class of '78), to whose care, skill, industry and persistence we are indebted for a series of very valuable determinations.

The results were tabulated by Mr. Jones, who, under the direction of the writer, also prepared a series of curves graphically representing them. The whole investigation was fully described in a graduating thesis.* The tables here given are usually presented with little or no material alteration as calculated by Mr. Jones in his thesis.

THE TERMS USED may be thus defined:†

The Modulus of Rupture for Tension is the force necessary to pull asunder a bar whose section is one square inch when acting in the direction of the axis of the bar.

The Modulus of Rupture for Compression is the pressure necessary to crush a piece of any material whose section is unity and whose length does not exceed from one to five times its diameter.

The Modulus of Rupture for Transverse Stress is the strain at the instant of rupture upon a unit of the section which is most remote from the neutral axis on the side which first ruptures.

The Modulus of Torsion is the ultimate resistance to torsion of a unit of the transverse section most remote from the axis of torsion.

The Modulus of Elasticity is a value which expresses the relation

* "Strength of Woods used in Engineering." By Frank P. Jones, M. E., '78. MSS; small 4to; pp. 75; folding plates xvii. Library Stevens Institute of Technology. 1878.

† See Woods' "Resistance of Materials," and "Report," by the writer, "on Cold-rolled Iron and Steel," Pamphlet. Pittsburgh, 1878. And also "Report on the Copper Tin Alloys." Washington: Government Print. 1879.

between the extension, compression or other deformation of a bar and the force which produces the deformation.

Resilience is a measure of the capacity of a material to resist shock, and its value is equal to the amount of energy expended, or the "work" performed in producing distortion or rupture.

The tension-tests gave the following results :

RESULTS OF TESTS BY TENSION.

Wood.	1	d	Modulus of Rupture.	Modulus of Proof Stress	Modulus of Elasticity.	Resilience.		EXTENSION. Per cent of length.	
						Ultimate.	Elastic.	Total.	At Elastic Limit.
	in.	in.						in.	in.
White Pine,	4	5.27	6877.5	3900	183486.2	2467.5	720.0	7.25	4.00
Yellow Pine,	4	5.32	2070.2	13200	240240.2	21457.0	3340.0	1.650	.625
Larch,	4	5.22	28925.2	19200	373831.7	31170.0	10792.5	1.850	1.100
Black Walnut	4	5.35	9786.4	5700	213523.1	4022.7	1530.0	.850	.525
White Ash,	4	5.44	15490.5	97000	206540.4	12655.0	3855.0	1.475	.775
White Oak,	4	4.81	13207.8	8100	220130.9	7500.0	3022.5	1.300	.770
Live Oak,	4	4.97	10309.2	6300	247505.2	5887.7	2167.5	1.150	.575

In calculating the results of tension-tests, as presented in the table, the *Resilience* was obtained, as in all other cases, by first plotting the results of test and obtaining a curve of which the ordinates measure loads and the abscissas the corresponding stretch or other form of distortion, then measuring the total area of the curve to obtain a measure of total resilience, or shock-resisting power, and by taking the area within the ordinate at the elastic limit as the measure of the elastic resilience.*

The *Modulus of Rupture* is measured by $R = \frac{P}{K}$; in which P is the load producing rupture, K is πr^2 , the sectional area at the point of fracture, and R is the modulus.

The *Modulus of Proof Stress* is similarly obtained, taking for P the load producing permanent distortion, as measured at the elastic limit.

The *Modulus of Elasticity* is $E = \frac{Pl}{yK}$; in which its measure, E , is obtained in terms of: P , which is the load at the elastic limit; l is the length of the part stretched, i. e., of the "neck" of the test-piece;

* The resilience, as usually defined, is *elastic* resilience. It should be carefully distinguished from *total* resilience. The one is proportional to the *work*, or the *elastic energy* required to produce permanent distortions; the other measures that required to produce fracture.

y is the extension at the elastic limit, and K is πr^2 , the area of cross-section at the part fractured. The position of the "elastic limit," so called, is necessarily assumed, since, as is seen by examination of the strain-diagrams, which graphically represent the results of these experiments, there is no definite elastic limit, the woods, as was shown by Hodgkinson to be the case with cast iron, having no true elastic limit; but take a set with any load however small. The point assumed is indicated in each case. It may be considered by many that a more strictly accurate measure would be obtained by deducing it from the direction taken by a tangent to the strain-diagram line at its origin. Either method will answer every practical purpose.

The calculations relating to compression were similarly made, assuming that the laws affecting wood under compression are the same as those acting when it is broken by tension—a practically correct assumption where the test pieces, as in this case, are crushed without lateral flexure.

THE RESULTS OF TEST BY COMPRESSION are presented in the following table:

RESULTS OF TESTS BY COMPRESSION.

WOOD.	l		Modulus of Rupture.	Modulus of Proof Stress	Modulus of Elasticity.	RESILIENCE.		COMPRESSION. Pct. of length	
	in.	in.				Ultimate.	Elastic.	Total.	At elastic limit
White Pine,	2·25	1·117	9592·6	5600	6521·8	19542·6	3534·3	3·498	1·584
Yellow Pine,	2·25	1·102	11952·3	7000	8576·9	16576·56	4107·18	2·906	1·485
Locust,	2·25	1·073	14818·9	9800	8713·8	26551·14	5761·14	3·300	1·617
Black Walnut	2·25	1·112	7001·7	5700	21060·5	5382·6	1561·56	1·254	·528
White Ash,	2·25	1·104	8148·3	5180	17810·0	12788·16	1898·82	2·310	·726
White Oak,	2·25	1·117	7143·5	5600	8029·0	15868·8	3940·86	3·300	1·551
Live Oak,	2·25	1·117	10409·2	6300	14910·5	23150·82	3100·02	3·366	1·056

THE TESTS BY TRANSVERSE STRESS gave results which are exhibited in the succeeding table. Here the modulus of rupture is $R = \sqrt{\frac{3}{2} \frac{Pl}{bd^2}}$; in which expression P = load producing rupture; l = the length of the test-piece between supports; b = its breadth; d = its depth; all measures are in inches, and loads in pounds.

In determining the Modulus of Proof Stress the same expression is used, taking for P , however, the proof load, or the load at the real or assumed elastic limit.

The Elastic and the Ultimate Resiliences here given are the number of

foot-pounds of work done in straining the specimens tested to the elastic limit and to the point of rupture respectively, and may be taken as approximate measures of the shock-resisting power of the material.

The Modulus of Elasticity, or the relation of the amount of distortion to the load producing it is determined by the expression:

$$E = \frac{P^3}{48 J I},$$

in which P is the load corresponding to a deflection, J ,

midway between supports; l is the length from support to support; J is the amount of deflection, and I the moment of inertia; for these

rectangular sections, $I = \frac{ba^3}{12}$.

RESULTS OF TESTS BY TRANSVERSE STRESS.

Wood.	l b d			Modulus of Rupture.	Modulus of Proof Stress.	Modulus of Elasticity.	RESILIENCE.		DEFLECTION.	
	in.	in.	in.				Ultimate.	Elastic.	Ultimate.	At Elastic Limit.
White Pine,	54	3	3	5280	4320	883636	1364.8	634.8	1.28	.86
Yellow Pine,	54	3	3	16740	12720	3534727	4174.4	2039.6	1.96	.84
Lobl.,	54	3	3	13680	8400	2046315	4843.2	1259.2	2.70	.82
Black Walnut,	54	3	3	7440	5640	1944000	971.6	433.2	.72	.50
White Ash,	54	3	3	9720	6360	1080000	533.3	1212.6	2.50	1.50
White Oak,	54	3	3	9840	7200	1620000	3660.8	1227.2	1.76	.90
Live Oak,	54	3	3	11280	9040	1851428	4601.6	1462.4	1.38	.94

TESTS BY TORSTON were made in the Autographic Machine, modified as already described.

Elasticity is measured by $E = \frac{r}{h}$, in which r is the measure of the recoil on removal of the load, and h the measure of the stress on the diagram taken from base-line.

Stiffness is measured by $S = \frac{m}{o}$, in which o measures the angle of torsion to the point considered (within the elastic limit), and m the value of the corresponding ordinate.

The Modulus is obtained by the expression $E = \frac{ml}{oh}$, in which m and o have the values assigned above; l = length of neck of test-piece, and h = its diameter.

The Resiliences, elastic and ultimate, come from the expressions $e = a \frac{m}{R} + P \frac{l}{R}$, and $E = A \frac{m}{R} + E \frac{l}{R}$, in which a is the area of

curve to the elastic limit; A is its total area; l = length of abscissa; R = radius of the drum carrying the sheet; m = foot-pounds per square inch of area of curve.

RESULTS OF TESTS BY TORSION.

Wood.	l	d	RESILIENCE.		Elasticity.	Stiffness.	Elastic Modulus of Resistance to Torsion.
			Ultimate.	Elastic.			
	in.	in.					
White Pine, ...	1	.780	5.10	.235	.....	.443	1.534
Yellow Pine, ...	1	.760	12.425	.238	.....	1.744	6.878
Locust, ...	1	.656	14.067	.178	.....	1.720	14.159
Black Walnut, ...	1	.785	7.396	.238	.....	1.088	3.650
White Ash, ...	1	.762	7.381	.560	.....	.598	2.328
White Oak, ...	1	.780	12.777	.396	.....	.911	3.155
Live Oak, ...	1	.656	14.570	.631	.....	.474	3.902

COMPARING AUTHORITIES on the strength of woods, it will be found that the results here recorded usually differ from those obtained by earlier experimenters, and that these figures are almost invariably higher than those of Barlow, Tredgold or Laslett, a fact probably attributable to the very uniform excellence in quality of the specimens tested, although it is possible that they may prove superiority of the American to the European timber.

The American timber, as here tested, gives figures in tension from one-eighth to one-fourth higher than the European woods reported on by Barlow or Tredgold, with the exception of ash. Tredgold's figures for American woods are, however, lower than those here presented, which is evidence of a difference in quality of test-pieces rather than of differences in the varieties of timber. The tables of resistance of timber given in Wood's "Resistance of Materials" accord more closely with those here obtained than do those given frequently elsewhere; they are, however, usually lower than these.

Comparing the results of torsional tests with those previously obtained by the writer,* by a similar method, they were found substantially to agree. The later experiments of Mr. Jones do not exhibit the peculiar phenomenon of a depression and subsequent re-elevation of the curve of the strain diagram which is exhibited in some cases in the earlier records. This may be due to the more complete

*"On the Strength, Elasticity, Ductility and Resilience of Materials of Machine Construction, etc." *Trans. Amer. Soc. of C. E., JOURNAL OF THE FRANKLIN INSTITUTE*, 1874.

seasoning of the test pieces last used, or to the action of the modified machine, which was less free from friction, and therefore somewhat less sensitive than was that first used by the writer.

In all cases the test-pieces here described were prepared from selected wood, straight-grained, free from knots or other perceivable defect, and may probably be considered as representative of the best quality of American timber, with the exception of the specimen of pine already mentioned. They were measured, when brought to size, by callipers, reading to $\frac{1}{1000}$ th inch.

Results were carefully corrected for the local crushing of the wood at points of contact with the machine.

The characteristics of the several woods are best shown by the autographic strain diagrams, of which two sets are given. The one giving the line of recoil when the load was removed at the elastic limit, the other exhibiting the full curve up to the point of final rupture. The areas of these curves were measured very carefully by Mr. Jones, using an excellent planimeter reading to $\frac{1}{1000}$ th square inch.

The results recorded in this paper are those obtained from the standard set of test-pieces. Repeated experiments on test-pieces from the same timber gave substantially the same results.

American timber has a value, in construction, equal, if not decidedly superior to, European timber.

The strength of American timber, as given by earlier authorities, is probably that of average specimens, and timber may be obtained by careful inspection of very much greater value.

Timber yields, under all forms of stress, to an extent which may be taken, as with cast iron, to be proportional to the load.

From what is above stated, and from a study of the strain diagrams, it may be concluded that the strength of timber is so variable that the only safe course in construction is to assume the highest values, determined by the most uniform series of tests of the material proposed to be used, and then to adopt a high factor of safety.

The tables above given may probably be taken to represent the probable values of resistance of the best selected woods, such as are passed by inspectors for naval purposes.

THE FUTURE WATER SUPPLY OF THE CITY OF
PHILADELPHIA.*

By JAMES F. SMITH, C. E.

So much has been said and written on the subject of the water supply of Philadelphia that one may well feel a delicacy in making any further reference to it. The writer has, however, devoted some leisure time and study to its consideration, and, in common with others, appreciates the great importance to the city of Philadelphia of a never-failing and abundant supply of pure and wholesome water.

In the year 1875, when the Commission of Engineers had under consideration the water supply of the city, the writer made certain suggestions, namely: First, the creation of a system of storage dams in the Schuylkill, where the river was not already occupied by the Schuylkill Navigation Company's works, and the use of several dams of the upper navigation, and the reservoirs now existing or to be created in the valley of Tumbling Run, near Pottsville; second, utilizing more fully the water-power at Fairmount and at Flat Rock dams, by raising these dams and increasing the volume of water from the storage dams when required; third, the building of an aqueduct to lead the water from the Flat Rock dam to the pumping stations at Spring Garden, Belmont and Fairmount, so that pure water might be supplied free from the contaminations and impurities of the Fairmount pool.

These plans were adapted to the wants of the existing water supply from the Schuylkill, and to the increase and improvement of the same. This supply is dependent upon steam-pumps with high lifts and inadequate water-power. Coupled with these disadvantages is the liability to breakage and derangement of pumps and power; whereas the people of a great city with dependent manufacturing establishments need a constant, reliable and ample supply of water of a purity that may not be questioned. Purity of supply can only be had by a resort to streams of water originating in the hills or ridges where the population is sparse and the country not extensively under cultivation. For

* A portion of this article appeared in the *North American*.

Philadelphia, the Perkiomen creek and its tributaries, rising in the spurs and ridges of the South mountain in Berks county, and in the elevated water-sheds of Bucks county, midway between the Delaware and the Schuylkill, is the source from which the water must come, and gravity the mode of its conveyance.

The citizens of Philadelphia have been made somewhat familiar with the question of a gravity supply from the Perkiomen by the consideration of Mr. Birkinbine's plan as given in the "Report of the Commission of Engineers" in 1875, and in his reports and papers on the subject.

The plan proposed by Mr. Birkinbine for an impounding reservoir is, indeed, favorable for the creation of a large lake, by the erection of a dam seventy or seventy-five feet in height, except in one particular, namely, the great length of the mound dam that would be required. The Commission of Engineers regarded this project with considerable favor, and gave credit, not improperly, to Mr. Birkinbine for his foresight in suggesting it. But at the site selected the water surface of the proposed lake would be too low for the city, except for the supply of the East Park Reservoir and the basins below its level, namely, Schuylkill, Corinthian avenue, Delaware and Fairmount; and from what has been said by the Commission, it will be observed that the conduit from this lake was not designed to deliver water into a receiving basin in the city at a greater elevation than 133 feet above city datum. This is manifest from what they say, namely, "that thorough and careful surveys should be made of the location of the line of conduit from the Perkiomen dam to the East Park Reservoir."

This deficiency in elevation, it must be admitted, is fatal to Mr. Birkinbine's location, as it would not be wise to build an aqueduct line to bring in the water of the Perkiomen, only to deliver it into the East Park Reservoir, at an elevation too low to supply Belmont, Frankford, or the proposed Cambria basins. The surfaces of the two former of these are respectively 212 and 168.40 feet above city datum, or 217.38 and 173.78 feet above mean tide, Delaware river, and the proposed Cambria basin about 170 feet above city datum.

My attention has but lately been called to an article on the subject of a gravity supply from the Perkiomen, by Chas. G. Darrach, C. E.*

Mr. Darrach proposes, instead of Mr. Birkinbine's lake, an inter-

* *Proceedings of the Engineers' Club of Philadelphia*, Vol. 1, No. 3, p. 162.

cepting canal around the valley, the supply for which is proposed to be taken from impounding dams to be erected on the main stream and its branches. This plan is ingenious and an improvement on that of Mr. Birkinbine in several particulars, namely, increased elevation, a delivery into the receiving basin of the city at an elevation of 170 feet instead of 133, and saving from destruction the Perkiomen railroad and the improvements in the valley which would be submerged by the lake.

Among the objections to the plan is still the want of elevation. A gravity supply to meet the future wants of the city of Philadelphia should deliver the water into the receiving basin at a much higher elevation than 170 feet of city datum, in view of the certain future extension of improvements and spreading of population over those parts of the city which are now suburban.

The plan for a gravity supply by aqueduct from Perkiomen, which I now propose, meets the objection of the want of height of Mr. Birkinbine's location. It will not require any alteration in the line of the Perkiomen Railroad, which would be necessary should a dam be erected near Schwenksville, and a large amount of valuable property in the valley of the main stream between that point and Green Lane would be saved from destruction.

THE LOCATION.

On the main stream of the Perkiomen, a few hundred yards above the Green Lane station of the Perkiomen Railroad in Montgomery county, eighteen miles above the mouth of the creek, there is an admirable site for a dam, at a point where the stream has broken through a ridge of hard rock, leaving a gap of little more than three hundred feet across with precipitous sides and solid foundations, just adapted to the erection of a safe and durable structure. At this place the dam may be 90 to 100 feet high, backing the water several miles into a valley, with favorable slopes bounded by hills and ridges.

From this dam I propose to carry the water by an aqueduct into the city, and the aqueduct would be so located as to command from 45 to 50 feet in depth of the storage water of the dam.

THE COURSE OF THE AQUEDUCT LINE—ITS LENGTH, TERMINAL BASIN AND ELEVATION.

The route may be thus described: Commencing at the storage dam.

or lake, and crossing the Perkiomen Railroad at a sufficient elevation above it, the aqueduct pursues a course nearly straight to the Plymouth Valley, passing a little west of the dividing ground between the waters of the Wissahickon and Plymouth creek, about twenty miles from the starting point at Green Lane.

Advancing from this point, after crossing the Plymouth Railroad, the line reaches Barren hill and passes through it into the Wissahickon valley; thence down that valley on the eastern slope of the ridge, crossing the stream, not far from Hermit's lane, to the high ground in the vicinity, where a distributing reservoir, of very moderate dimensions, in connection with the several existing basins of the water-works and the East Park Reservoir when completed, would suffice, and furnish a storage capacity of nearly one billion of gallons. The length of the proposed aqueduct line is about $27\frac{1}{2}$ miles, and the location such that the water may be delivered into a receiving reservoir, the surface of which might be 240 feet above city datum, with a free delivery from the aqueduct itself, the water surface of which when running in its full capacity would be nearly 249 feet above city datum, or 254 feet above mean tide Delaware river.

It may be stated here in regard to the line of the conduit, that whilst none of the valleys to be crossed will require long and elevated structures of masonry, there will be several tunnels, mostly through sand-stone. Below Barren Hill the work will encounter mainly gneiss rock. This feature is deemed favorable, as tunneling at the present time, owing to improved methods and explosives, can be done with such great facility that in most cases the expense will be less than for an aqueduct of masonry, and especially so where the rock encountered is found to be of a character to justify the omission of interior brick linings.

TRIBUTARIES OF THE PERKIOMEN INTERCEPTED.

In the first $10\frac{1}{2}$ miles a number of important streams are passed. Three of them are main branches of the Perkiomen, and three affluents of these branches. They originate chiefly in the hills dividing the waters of the Delaware from the Schuylkill in Montgomery and Bucks counties, more than 500 feet above tide, and extremely favorable for maximum precipitation. It is part of the plan that these streams shall be made tributary to the water supply by the erection of impounding dams or small lakes upon them, with dams of the heights and capacity

suited to their drainage areas and the quantity of water required to be stored. The cost for all of them will not, it is believed, be more than for the dam, and the land and improvements that would be submerged and destroyed by the lake at Schwenksville and the reconstruction of ten miles of railroad would be saved. At first the construction will be limited to the works at Green Lane and the aqueduct line to the city, leaving the improvement of the tributary streams to be undertaken one by one, in the future, as the increase in population of the city may demand more water for consumption.

CAPACITY OF THE PERKIOMEN WATER SHED.

The water shed of the Perkiomen above Green Lane station is about seventy-three square miles, and with the tributary streams crossed by the aqueduct line added there is not less than 200 square miles. If 59 per cent. of the annual rainfall of 47.82 inches be taken as collectable (being one-fifth greater than that of the year 1858 at Philadelphia, and which Mr. W. J. McAlpine, C. E., has taken in his calculations for the Perkiomen, *vide* report of Commission of Engineers, 1875), it would give daily 272,000,000 gallons. Of this quantity it may be assumed that 165,000,000 gallons daily average supply to the conduit may be taken, leaving, after deducting for soakage, evaporation and waste of the impounding dams, nearly 100,000,000 gallons to pass away as surplus or flood water. From the Perkiomen above Green Lane village 60,000,000 gallons daily of the supply may be furnished, and when the consumption of water is greatest, in July or August, 72,000,000.

The drainage areas of the streams above the aqueduct line have been determined from measurements and calculations based upon a corrected map of the townships of Montgomery and parts of Bucks and Berks counties, which was specially prepared for the purpose. The results are believed to be fair approximations, and are given in the following table:

TABLE 1.

	Square miles.
Perkiomen Creek at Green Lane, ...	73.00
Great Swamp Creek, ...	34.47
Ridge Valley—affluent of Swamp Creek, ...	9.64
East branch of Perkiomen, ...	46.00
Indian Run—affluent of east branch, ...	6.04
Skipack Creek, ...	21.48
Towamencin—affluent of Skipack Creek, ...	10.55
Total, ...	201.18

Macoby Creek, a stream having a drainage area, above the aqueduct line, of $17\frac{1}{2}$ square miles, flows into the Perkiomen at Green Lane, south of the railroad, but is omitted to avoid any interference with the road, which occupies the valley for several miles. This stream may be utilized to the extent probably of 10 square miles of its drainage area without injury to the railroad.

In the annexed table is given both the annual and the average daily flow of the seven streams, based upon the utilization of 28.41 inches of the rainfall upon the Perkiomen water shed; also the reservoir capacity required above the limit of draught in the impounding dams for a given consumption.

TABLE 2.

Name of Stream.	Collectable annually— Million U. S. gallons	Daily average gallons	Daily average demand for consumption —Million gallons	Deficiencies to be provided for by reser- voirage dam— Million galls.
Perkiomen Creek,	36,041	98,742,466	60	3,996
Great Swamp Creek,	17,053	46,720,548	28	1,822
Ridge Valley,	4,751	13,016,438	8	560
East branch,	22,735	62,287,671	38	2,530
Indian Run,	2,959	8,106,849	5	365
Skippack Creek,	10,465	29,164,383	18	1,215
Towamencin,	5,193	14,227,397	8	592
	99,377	272,265,752	165	11,090

This table is constructed upon the basis of 47.85 inches annual rainfall, or one-fifth more than that of the year 1858 at Philadelphia, as assumed by Mr. McAlpine.

There are no records of rainfall upon the Perkiomen in years past with which comparison might be made to establish the correctness of the above assumed data. We have, however, actual results obtained from storage reservoirs in constant use in Eastern Pennsylvania, one example of which will suffice.

The Silver Creek reservoir of the Schuylkill Navigation, on the Broad Mountain in Schuylkill county, has a drainage area of $1\frac{1}{2}$ square miles. This water shed is rolling table land, not rising in any part to the dignity of a hill, and therefore not very favorable to the flow of a large percentage of rainfall into the reservoir. Notwithstanding this fact it is filled at least twice every year, and this has been the experience of many years. Its capacity is 320,000,000 gallons, and the total quantity stored and utilized for supplying the navigation

is $320,000,000 \times 2 = 640,000,000$ gallons, $= 28.82$ inches of rainfall over $1\frac{275}{1000}$ square miles.

Upon the basis of this quantity utilized from $1\frac{275}{1000}$ square miles, applied to the Perkiomen drainage area of 201 square miles, we have 101,000 million gallons, as against 99,377 million gallons collectable from 28.41 inches of rainfall (Table 2).

It may be said that the region of Silver Creek, being at an altitude of 1500 feet above the level of the sea, is more favorable for rainfall than the Perkiomen district.

Distances and Fall of Aqueduct Line (circular).

NAME OF STREAM.	Distance from the reservoir.—Miles.	Total distance (per map).—Miles.	Total distance with allowance for deviation.—Miles.	Fall or descent.—Feet.	Total fall.—Feet.	Assumed level of water surf. in the aqueduct above C. D.—Feet.
West branch (Perkiomen), ...	0	0	0	0	0	275
Great Swamp Creek, ...	1.375	1.375	1.39	$\frac{1}{3400}$	2.159	262.84
Ridge Valley, ...	0.500	1.875	1.89	$\frac{1}{4075}$	2.445	272.55
East branch, ...	1.875	3.750	3.80	$\frac{1}{4253}$	4.720	270.28
Indian Run, ...	1.250	5.000	5.05	$\frac{1}{4976}$	5.350	269.65
Skippack Creek, ...	3.875	8.875	8.95	$\frac{1}{5000}$	9.450	265.55
Towamencin Creek, ...	0.875	9.750	9.85	$\frac{1}{5400}$	9.630	265.37
Stony Creek Railroad, ...	4.625	14.375	14.52	$\frac{1}{5597}$	13.690	261.31
1st branch crossing Stony Creek, ...	0.875	15.250	15.40	$\frac{1}{5597}$	14.530	260.47
2d “ “ “	1.000	16.250	16.40	$\frac{1}{5597}$	15.470	259.53
3d “ “ “	1.500	17.750	17.93	$\frac{1}{5597}$	16.910	258.09
Plymouth Railroad Summit, ...	2.250	20.000	20.20	$\frac{1}{5597}$	19.050	255.95
Wissahickon, ...	6.875	26.875	27.15	$\frac{1}{5597}$	25.610	249.39
School Lane (high ground), ...	0.375	27.250	27.50	$\frac{1}{5597}$	25.940	249.06

I need only refer to so eminent an authority on climatology as Lorin Blodget in support of the contrary opinion. Mr. Blodget places the Schuylkill county region within the range of 40 inches mean rainfall, as against 42 inches in the Berks, Montgomery and Philadelphia districts, and, in an article on the climatology of Pennsylvania, says, fur-

ther: "The heaviest rainfall is in the southeast, where the annual mean is 48 inches, and the greatest quantity in any one year is about 60 inches. This represents the first range of hills back from the Delaware River, on which more rain falls than on the plains of New Jersey and Delaware, nearer the sea. West of the hills, and in the Susquehanna Valley, the quantity of rain falling is much less, only about 38 inches."

The first range of hills referred to by Mr. Blodget are those in which the Perkiomen and its branches take their rise, and in this connection it may be stated as a fact that freshets on this stream are more frequent, and higher in proportion to the drainage area, than on the upper Schuylkill.

Quantity of water required for consumption in the month of July, based upon the rainfall of the year 1858, augmented by $\frac{1}{2}$ for the Perkiomen, as per table, and increased from the average daily consumption by 120 per cent., being the assumed percentage for that month.

NAME OF STREAM.	Average daily consumption. — Million gallons.	Quantity for consumption to be carried by the aqueduct. — Million gallons.	Total quantities. — Million gallons.	Diameter of aqueduct and low raised in size for each stream taken in. — Feet.	Capacity of aqueduct containing full. — Million gallons.	Velocity per second. — Feet.
West branch (Perkiomen),	60	72.1	72.1	8.000	73,244	2.25600
Great Swamp Creek, .	28	33.6	105.7	9.625	106,177	2.25800
Ridge Valley, .	8	9.6	115.3	10.042	115,545	2.25800
East branch, .	38	45.6	160.9	11.750	158,236	2.25800
Indian Run, .	5	6.0	166.9	11.917	163,475	2.25800
Skippack Creek, .	18	21.6	188.5	12.750	185,491	2.25388
Towamencin Creek,	8	9.6	198.1	13.181	195,000	2.25388
	165	198.1				

This table has been computed for the velocity, from the formula of Robert K. Martin, C. E., and used by him for the air-line conduit 12 feet diameter, for the permanent water supply of the city of Baltimore from the Great Gunpowder Falls. This work is a tunnel 36,495 feet long, from the dam on the Gunpowder River to an artificial reser-

voir (Lake Montebello, near Baltimore), having a storage capacity of 600 million gallons, and elevated above mean tide 163 feet.

Mr. Martin's formula is :

$$V = \sqrt{\frac{180 \times H \times D}{l}}$$

$$= \sqrt{\frac{2 g H}{0.007454 r^5}}$$

in which H = head, in feet

D = diameter, in inches

l = length, in feet

$$r = \frac{d}{4}$$

The diameters given in the above table are for a conduit running full. For the Perkiomen, another form is preferred, which will admit of a maximum flow limited to a surface sufficiently below the crown of the arch; $17\frac{1}{2}$ miles to be of the full capacity for maximum delivery (about 12 feet wide by 13 feet in height), the remainder varying to meet requirements, beginning with 8 feet width and height.

Swamp Creek, rising in Berks county, near Boyertown, and flowing into the Perkiomen below the village of Zieglerville, has not been included in the general plan, because many years must elapse before it will be needed, but it can be utilized whenever required, and its waters brought into the main storage lake near Green Lane by means of a branch conduit. Its drainage area above the height of the Green Lane lake is about 30 square miles.

ADVANTAGES OF THE PROPOSED PLAN.

Some of the advantages of this plan will appear from the following considerations :

First. It will supply, from one point alone, a greater quantity of water than is now required for the present population of the city. Second. It will deliver the water to a basin at an elevation of 27 feet above Belmont, 72 feet above Wentz's Farm, 69 feet above the proposed reservoir at Thirtieth and Cambria streets, 104 feet above East Park, 119 feet above Schuylkill and Corinthian, 125 feet above Delaware and 145 feet above the Fairmount basins. Third. It can supply Roxborough and Mount Airy basins by a pumping station at the aqueduct where it passes not far from the former, and save more than

200 feet in the lift encountered at the present Roxborough pumping works, beside permitting them to be discontinued, and the long line of pipes in the pumping main taken up and utilized elsewhere. Fourth. It can supply a basin, which may be provided for the service of Manayunk, by a pipe line or branch conduit, tapping the aqueduct line in the Wissahickon Valley, and obviate the necessity for a supply, as at present, from the Roxborough reservoir. Fifth. It will obviate the necessity for all the present steam-pumping stations with their expensive and, in some cases, troublesome monster pumps, and leave Fairmount and its water power, when disconnected from the basins, to be run moderately in the summer, to feed lakes and fountains in the Park or for flushing main sewers.

It remains now only to say that the correctness of my statements as to the route for the aqueduct and the capacity and availability of the water sheds are subjects for investigation by submission to instrumental examinations by competent parties in the field, and when this is done, the cost, to which I have not referred, may be estimated very closely. The work, as far as possible, should be monumental in its character, and whilst no money need be spent for mere show or unnecessary ornamentation, yet nothing should be left undone that may contribute in the least degree to strength and durability. In the tunnels we shall have the everlasting rocks; along the slopes rock cuttings, and over streams and valleys permanent structures of stone or iron. The impounding dams must be of undoubted strength, as they certainly may be if founded upon the rock and built of solid impermeable materials, and so on with all other parts.

The cost of the work would not be so large as that of the Croton Aqueduct—40½ miles long—which cost originally \$8,575,000; but as the completion for a full capacity of aqueduct will not be required for many years, neither will the full expenditure. The cost, whatever it may be, can be spread over several years, and will not be so much of a burden that it cannot be borne by a people who steadily look forward to the time when the city of Philadelphia will embrace within its limits a population of two million souls.

Perkiomen Creek above Green Lane.

	Rainfall at Philadelphia in 1858.	Rainfall on Perkiomen, estimated one-fifth greater.	Percentage of the rainfall collectable in each month.	Inches of rainfall collectable.	Millions of gallons collectable from 73 sq. miles.	Inches of evaporation from reservoirs per month.	Evaporation in millions of gallons.	Waste and loss from all sources.—Million gallons.	Percentage of consumption per month.	Consumption at an average of 60 million gallons per day.—Million gallons.	Total demand from reservoir.—Million gallons.	Surplus.—Million gallons.	Deficiency.—Million gallons.
January,	2.60	3.12	90	2.81	3,564	1.15	17	12	82	1,525	1,554	2,010	1722
February,	2.29	2.75	80	2.20	2,791	1.65	24	12	83	1,394	1,430	1,361	758
March,	1.09	1.31	70	0.92	1,167	0.82	11	12	85	1,581	1,604	.....	1148
April,	4.64	5.57	60	3.34	4,237	2.07	30	12	94	1,692	1,734	2,503	368
May,	5.01	6.01	50	3.00	3,806	1.62	24	12	105	1,953	1,988	1,818	.....
June,	4.50	5.40	40	2.16	2,740	7.10	105	12	115	2,070	2,187	553	.....
July,	1.35	1.62	30	0.49	622	6.75	100	12	120	2,232	2,344	.....	1722
August,	4.94	5.93	20	1.19	1,510	7.79	117	12	115	2,139	2,268	.....	758
September,	1.49	1.79	40	0.72	913	5.41	87	12	109	1,962	2,061	.....	1148
October,	1.83	2.21	60	1.33	1,687	7.40	109	12	104	1,934	2,055	.....	368
November,	5.62	6.74	80	5.39	6,838	3.95	58	12	100	1,800	1,870	4,968	.....
December,	4.50	5.40	90	4.86	6,166	3.66	54	12	88	1,637	1,703	4,463	.....
Aggregates & Averages,	.....	47.85	59½	28.41	36,041	49.37	736	144	100	21,919	22,798	17,676	3996

Aggregates and Averages for all the Streams, based upon the drainage areas which may be utilized for the supply of the Aqueduct.

NAMES OF STREAMS.	Drainage areas. — Square miles.	Rainfall at Philadelphia in 1878.	Rainfall on Perkiomen, $\frac{1}{2}$ greater.	Percentage of the rainfall collectable per annum.	Inches of rainfall collectable per annum.	Million gallons collectable from drainage area.	Inches of evaporation from reservoir per annum.	Evaporation. — Million gallons per annum.	Waste and loss from all causes, per annum.	Consumption, daily average. — Million gallons.	Annual consumption. — Million gallons.	Total demand from reservoir. — Million gallons.	Surplus. — Million gallons.	Deficiency. — Million gallons.
Perkiomen (Green Lane),	173	39.85	47.85 59 $\frac{1}{2}$	28.41	36,041	49.37	736	144	60	21,919	22,798	17,676	3,996	
Great Swamp Creek,	34.5	39.85	48.85 59 $\frac{1}{2}$	28.41	17,053	49.37	308	120	28	10,228	10,656	8,432	1,832	
Ridge Valley,	9.64	39.85	47.85 59 $\frac{1}{2}$	28.41	4,751	49.37	99	72	8	2,913	3,084	2,301	560	
East branch,	46	39.85	47.85 59 $\frac{1}{2}$	28.41	22,735	49.37	465	120	38	13,893	14,478	11,120	2,530	
Indian Run,	6	39.85	47.85 59 $\frac{1}{2}$	28.41	2,959	49.37	65	60	5	1,836	1,964	1,395	365	
Skippack Creek,	21.5	39.85	47.85 59 $\frac{1}{2}$	28.41	10,645	49.37	207	96	18	6,577	6,870	5,142	1,215	
Towamencin,	10.5	39.85	47.85 59 $\frac{1}{2}$	28.41	5,193	49.37	104	84	8	2,912	3,090	2,645	592	
Totals,	201.14	39.85	47.85 59 $\frac{1}{2}$	28.41	99,377	49.37	1,984	696	165	60,278	62,937	48,711	11,090	

In this connection there is now one other matter that deserves the most serious consideration, and which should be an incentive to early action by the people. It is this, that long before the population shall have reached the figure named, the waters of the Schuylkill will have become so contaminated by sewage, in consequence of the great increase in population along its banks, as to be totally unfit for domestic purposes; even the next decade may produce a marked change, hence there is no time to be lost in determining the course that should be adopted to secure pure water for domestic as well as for manufacturing purposes. Much time must necessarily elapse, in any event, before a work adapted to the wants of the city can be brought into use. All the Delaware schemes are too costly, as was shown by the commission in 1875, and require no further consideration.

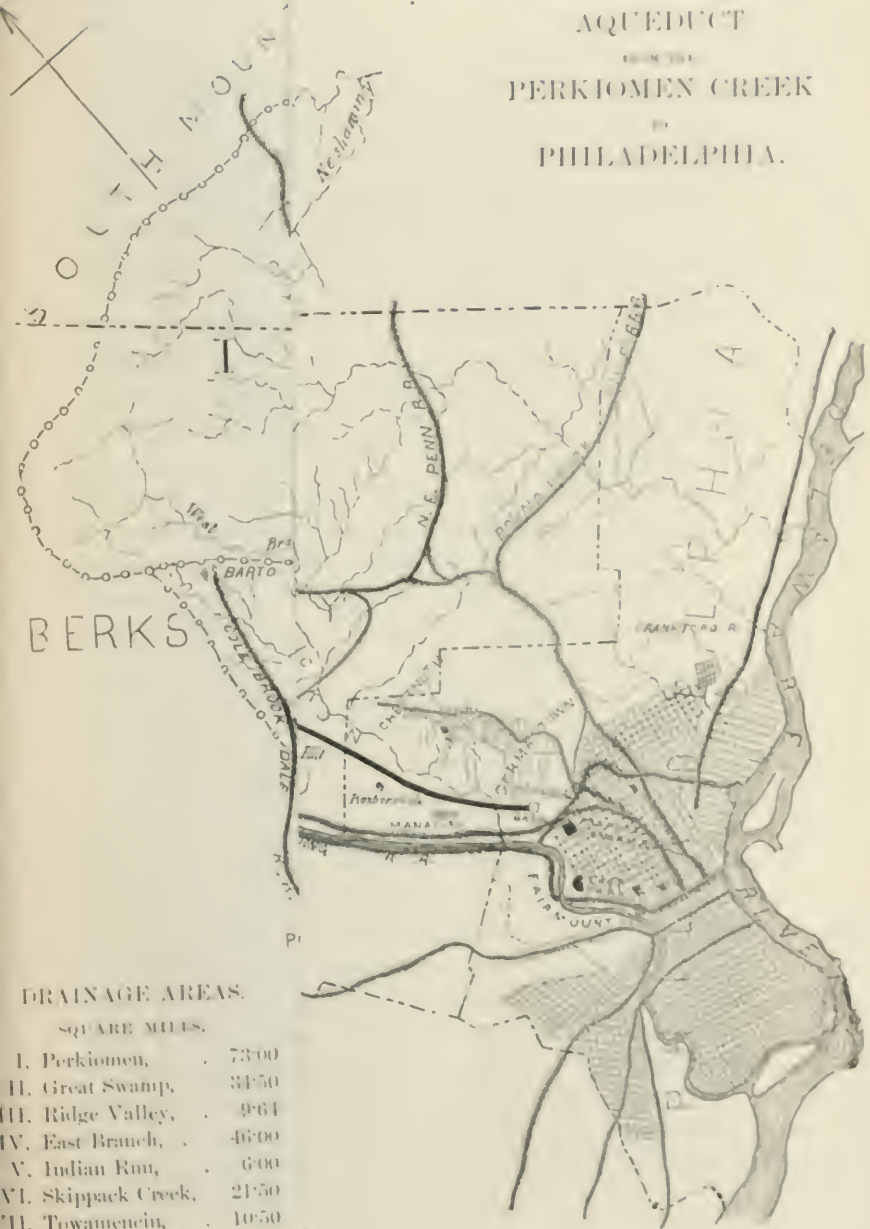
So, after all that has been said and written upon the subject of the water supply for the future, if not notably for the present, there is no other stream, in my judgment, of equal purity with the Perkiomen within reasonable distance from which an adequate, pure and never-failing supply can be brought; and in closing this paper I must remark that I very cheerfully resign to Mr. H. P. M. Birkinbine the credit of pointing out that stream, and for myself only claim the plan of tapping it at a higher and more favorable point and intercepting and utilizing the headwaters of its principal branches, which fortunately lie in the track and cross a direct aqueduct line to the city over high ground.

On Artificial Atropia.—As is known, atropia on treatment with barium hydrate is decomposed into tropine and tropic acid, according to the reaction: $C_{17}H_{23}NO_3 + H_2O = C_8H_{15}NO + C_9H_{10}O_3$.

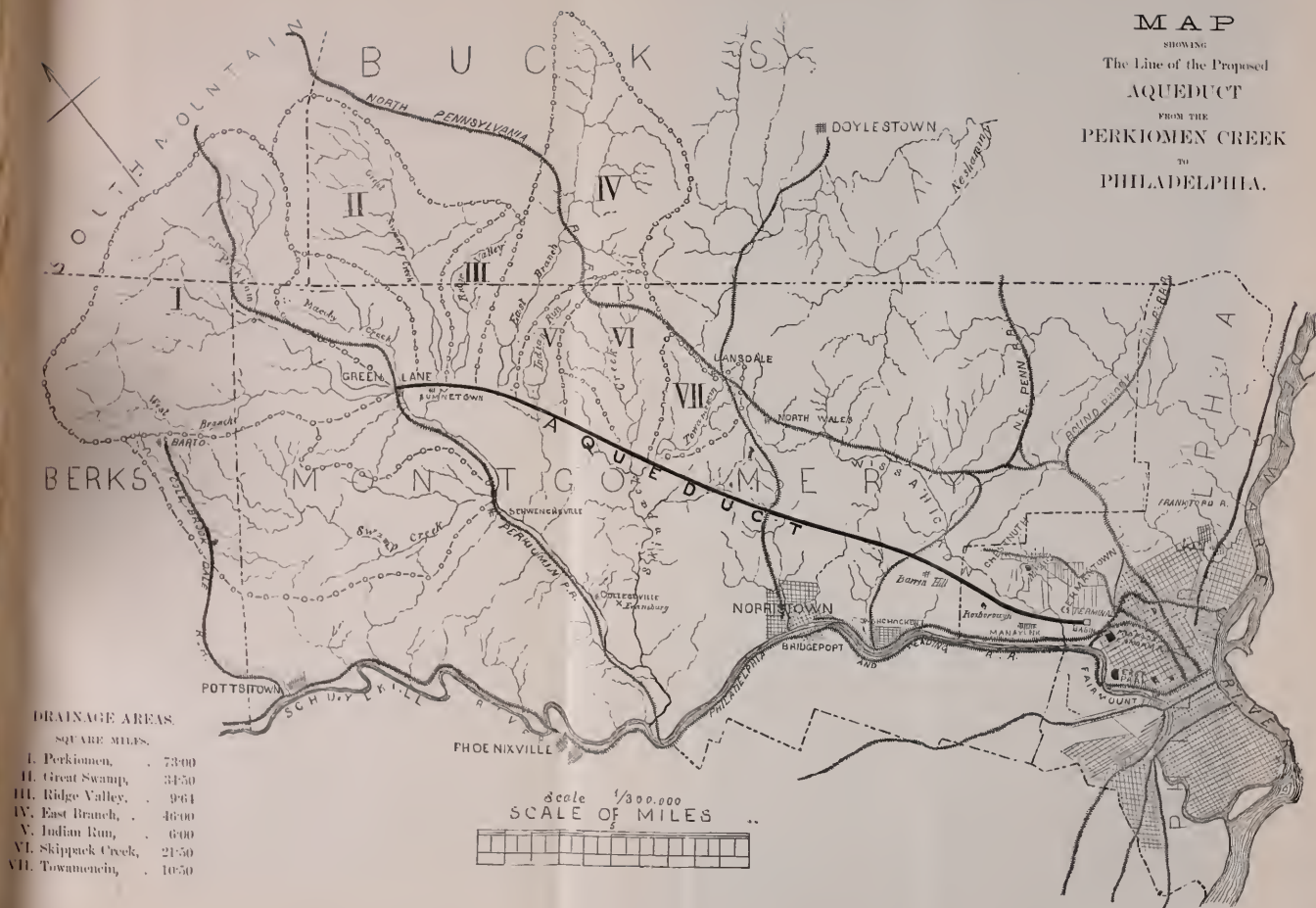
The first, and perhaps most important step in the synthesis of atropia, is the re-combination of these decomposition products to form the alkaloid again. This Ladenburg has just accomplished by treating the tropate of tropin with dilute hydrochloric acid at 100°. The tropin tropate used was in colorless crystals and gave no reaction for atropia, even when in 15 per cent. solution showing no action upon the eye. After the treatment for some time with an excess of dilute hydrochloric acid, an oil separated out, which, when purified, solidified to a mass of colorless needles. The author was unable to find any difference between the artificial atropia so prepared and the purest natural product.—*Ber. der Chem. Ges.*

MAP

The Line of the Proposed
AQUEDUCT
FROM THE
PERKIOMEN CREEK
TO
PHILADELPHIA.



MAP
SHOWING
The Line of the Proposed
AQUEDUCT
FROM THE
PERKIOMEN CREEK
TO
PHILADELPHIA.



HELIOGRAPHY, OR PHOTOGRAPHY IN THE
PRINTING PRESS.

By JOHN CARBUTT.Read before the Franklin Institute at its meeting Sept. 17th, 1879.

The Secretary having desired me to describe to the members of the Franklin Institute how photographs in printing ink are made; before doing so permit me to read from an article prepared by me a short time since for one of our journals—"The Photographic Rays of Light."

In 1796 Alois Senefelder, of Munich, a musician and composer, was in the habit of using pieces of slate or limestone, on which to arrange his compositions before putting them on paper.

While so engaged he wrote with pencil, on a piece of this stone, a memorandum for his mother. Accidentally it fell into a vessel containing greasy water; to his astonishment he saw that every letter had become coated with grease contained in the water, and without affecting the other parts of the stone. This simple accident led him to the discovery of lithography, and little did he dream at that time of the marvelous results now obtained through the means of his invention, or that a chemically prepared surface would be discovered on which, by the action of light, natural objects, portraits and works of design and construction would be drawn, which, when placed in the printing press, would yield, by a process of printing strictly analogous to his own, copies of such objects in permanent pigments.

In 1839 Mungo Ponton, of England, discovered that when paper coated with a solution of bichromate of potassium, and after drying was exposed to light under a drawing, that it received an image, of a brown color, to preserve which it was only necessary to wash the paper in water to remove the bichromate not acted upon by the light. This, as far as known, is the first instance of a picture having been produced by the action of light on a body impregnated with a bichromate salt.

In 1854 Paul Pretsch made known his discovery that a film of gelatine and bichromate of potassium, after exposure under a drawing or other design to light, and after damping with water, would receive ink from a roller passed over its surface where the light had acted upon it, and refuse it where the light had not acted, owing to those parts hav-

ing absorbed water, thus producing a printing surface strictly analogous to the drawing made by Senefelder on the lithographic stone; but Pretsch only used these inkable images to obtain a transfer to be laid down on stone to be printed from.

In 1855 Louis Poitevin made further advance in the use of a bichromatized gelatine film, by producing pictures in half-tone, but nothing of a really practical nature was accomplished by him at that time, as the films would bear but a few impressions to be taken from them.

In 1865 Tessie du Motay, of Metz, France, made still further progress in half-tone printing from a gelatine surface, making use of copper plates as a support for the gelatine film, and from which seventy to eighty impressions could be obtained. The results were considered so good at that time that soon other experimenters took up the subject. Notably to Albert, and Obernetter, of Munich; Rye, of Denmark; Gemoser, of Berlin; Despaqui, of Paris, and Edwards, of London, is due great credit for the perfection to which heliography, light-drawing on a bichromatized gelatine surface, has been brought.

Before describing the making of and printing from a heliograph plate I will briefly explain the similarity between a drawing by hand on a lithograph stone and a drawing by light on a bichromatized gelatine film.

To produce a design upon stone the artist makes use of a crayon or ink composed of materials of a fatty nature, on completion of which, if the stone is sponged with water, it will be seen that the water recedes from that portion covered by the design, but is readily absorbed by the stone outside of the design. On passing over it a roller charged with lithographic ink it will be seen to deposit on the drawing but not on that part of the stone yet moist from the water, the greasy nature of the drawing attracting the ink while the water repels it.

If a bichromatized gelatine film be exposed to light under a negative the result will be an image or drawing, of a brown color; on placing the plate supporting this film in water it will be seen that where the light has had full action so as to reduce all the bichromate it refuses to absorb water, and where the light has not acted it absorbs water freely and swells up. On blotting off the surplus water, and passing over it a roller charged with lithographic ink, it will be seen to deposit on the parts acted on by light, but refuses to deposit on the parts that have absorbed water, thus establishing the relation analogous to a drawing on stone as regards its acceptance or rejection of a

greasy ink when in a moist condition. This is the relation produced by Pretsch's discovery in 1854, who, like Senefelder, never dreamt of the wonderful results now being daily accomplished by the aid of the camera and printing press. The drawing produced by light, first through the aid of the camera and then by the negative thus obtained on the bichromatized gelatine plate, has a far greater intrinsic value than a drawing produced by the hand of man, be it ever so skillfully executed; for what can exceed the faithfulness with which photography pictures everything placed before the camera? Is not the drawing executed by nature's self?

Heliography—"sun-drawing"—then, is a process by which a picture is produced by light on a chemically prepared surface from which by mechanical means prints in permanent ink can be produced with a celerity and cheapness, delicacy of texture, exquisite gradation, and faithful rendering of detail, that when limited numbers are required will give heliographic productions the preference over other processes of the sister arts.

I will now describe to you how the gelatine printing surface is produced. The support for the gelatine may be of zinc, copper, stone or glass; the latter, being best adapted to the purpose, is most generally used. To secure the gelatine film to the glass, so as to allow of a large number of impressions being pulled, it was found necessary to first coat the glass with a thin substratum of gelatine, albumen and bichromate of potassium; albumen and bichromate; or albumen and silicate of soda; one or other of these preparations is essential to the production of a good printing plate; all are patented, and the patents for these and other improvements are owned by a company in New York known as the Artotype Company, who grant licenses for working them. I hold the exclusive right for photo-mechanical printing for Philadelphia and 25 miles radius.

If one of the first two formulas for a first or cement coating is used, the plate after drying is placed, face down, on a board covered with a black cloth or velvet, and the light allowed to act through the glass for a time sufficient to cause that side of the coating next the glass to have become insoluble; it is then carefully coated with a solution of fine gelatine, containing 15 to 20 per cent. of bichromate of potassium or ammonium, placed in the drying box, which is a rectangular one having cross bars, supplied with screws, on which the glass plates have previously been brought to an accurate level; and dried at a tempera-

ture varying from 110° to 130° Fahr. When dry the plate is ready for exposure under a negative; the usual printing frame used by photographers is made use of, but as we cannot examine the progress of the light's action as in photograph printing, the back of the printing frame is dispensed with, the plate being held in close contact with the negative by wedges placed under the cross bars, and we examine the progress of printing through the back of the plate. When all the detail of the image is visible, the plate is removed from the printing frame and placed in cold water, which dissolves out the bichromate not reduced by light. When sufficiently freed of the now useless bichromate it is allowed to dry. Before putting it on the press the plate is placed for a few minutes in a pan of water. It is then freed from water on the back, placed on the bed of a lithograph press, the surface carefully sponged, and dried with a soft cloth or other means. At this stage a faint image only is visible, and on passing over it a roller charged with a stiff ink those parts answering to the transparent parts in the negative will take ink with considerable freedom, while those parts answering to the half-shades will take much less, and where no light has acted will refuse ink entirely, from the film having so freely in those parts absorbed water. The printer now takes a roller similar in composition to those used in type printing and charges it with the same or a colored ink, but reduced in stiffness with oil or thin varnish, and with very little on the roller. Passing this roller over the plate it continues the inking up of the image until the faintest detail is made visible. A mask of paper having an opening of the size of the subject on the plate is laid over it, a piece of fine paper laid on, the tympan lowered, and with a light pressure pulled through the press, when, if all the conditions have been properly carried out, a print possessing all the delicacy of a fine photograph, but in a pigment as durable as that of the engravings of old, and with all the minuteness of detail and delicacy of light and shade that photography so faithfully gives us.

Heliographic printing is applicable to any kind of subject that can be photographed, and for publishers and manufacturers offers the best means of producing portraits, landscapes, machinery and all kinds of manufactures; reproduction of engravings, paintings and original drawings, old manuscripts, etc., and for illustrating art and manufacturers' catalogues.

Artotypes are executed in any of the permanent printer's inks, and

at much less cost than photographs. To produce the best results special negatives are required to produce the printing plate, and care and skill is required of the printer. The Artotype specimens exhibited before you to-night will, I think, convey some idea of the practical application of heliography.

COLOR-BLINDNESS IN RAILWAY EMPLOYEES.

The evidence furnished by recent examinations of railway men discloses the fact that color-blindness exists to an extent scarcely suspected a few years ago. In all cases where there is direct conflict of evidence as to the state of the signals it would be at least advisable to have the witnesses tested for color-blindness. Dr. Keyser, of the Wills Eye Hospital, Philadelphia, has recently examined a number of railway employees engaged on the systems centering in that city, and according to his report to the State Medical Society, $3\frac{1}{2}$ per cent. of the whole number mistook colors, and $8\frac{1}{2}$ per cent. additional were unable to distinguish accurately the shades of colors. The mistaking of colors was doubtless due in large part to defective vision; blunders in shading are probably due to lack of training. The condition of the eyes was carefully examined with the ophthalmoscope, and of the number under examination 79 per cent. were found of perfect vision and 21 per cent. defective; of the color-blind, 47 per cent. were of perfect vision and 53 per cent. defective; of those who only shaded badly, 77 per cent. were of perfect vision and 23 per cent. defective. Of those found defective, 50 per cent. were green blind, 44 red and 6 blue. Of the $8\frac{1}{2}$ per cent. defective in shading, 95 per cent. were so in greens and 5 per cent. in red. Two men who could not distinguish red from green on tests, had educated themselves to know that red was an intense color, and thus distinguished bright red signals, but at the same time bright greens and other bright colors were red to them. For these they would stop their trains, and so err on the safe side. On the other hand, dark reds, dark greens, and browns were all one to them, thus making those colors useless as signals. Another peculiarity in one case was the ability to distinguish bright red close by, but not at a distance. A color correctly recognized as bright red at three feet was invariably called green at ten feet and beyond. The test methods employed were those of Prof. Holmgren, Dr. Stilling and others.—*English Mechanic.*

STEAM-BOILER EXPLOSIONS.

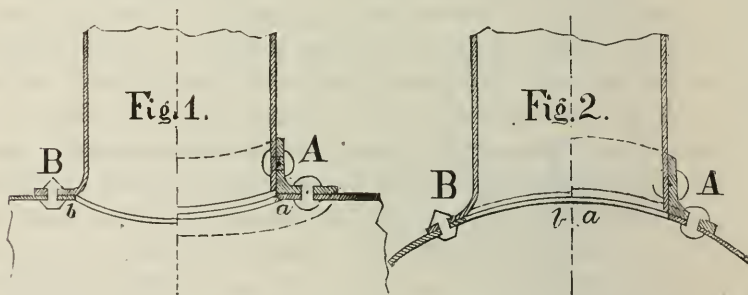
By JOHN W. NYSTROM.

Read before the Franklin Institute at its meeting Sept. 17th, 1879.

The steam-boiler explosion at the mill of Wilt & Son, Philadelphia, on June 29th last, has caused some controversy among engineers and in the daily papers about its cause, and also as to the strength and weakness of steam boilers in general; and in discussing the subject with the Secretary of the Institute, he invited me to explain my ideas of the same at the September meeting. The accompanying illustrations are prepared to show the principal cause of the majority of steam-boiler explosions, namely, the construction of the joints of necks and steam-drums to the main shell of the boiler.

Experiments were made in England some years ago to find the weakest point of steam boilers, and it was found that where the main shells of cylindrical boilers were cut for man-holes, neck or steam-drums, these parts were the weakest and gave way first under excessive pressure.

The Wilt & Son steam boiler burst at the necks between the main shell and steam-drum, which were the weakest points.



The accompanying illustrations represent a longitudinal section, Fig. 1, and a cross-section, Fig. 2, of parts of a boiler and neck, showing two different modes, A and B, of connecting a neck or drum with the main shell. The strongest joint is that represented at A, namely, to bend an angle-iron to fit the joint and rivet the same to the neck and shell. A double row of rivets in the shell would be better. The

angle-iron should be welded to form a solid ring. The ordinary mode of connection is represented at *B*, namely, to flange the neck and rivet the same to the shell with one row of rivets, which is now generally done in all boilers with necks or steam-drums; but the strength of this joint is very deceptive, being only a small fraction of that of the shell without the hole, whilst the joint *A* can be made fully as strong as the shell.

I have spoken to several boiler makers about the angle-iron joint, *A*, but they do not seem to appreciate its value, nor do they apprehend the weakness of the joint *B*. Mr. Longstreth, of the Baldwin locomotive works, objects to the joint *A* on the ground, he says, that "angle-iron is generally made of very poor iron." This objection can be overcome simply by ordering angle-iron of the best quality of iron or of cast-steel. Mr. Le Van says, "the angle-iron joint requires two rows of rivets, two seams for caulking, and it is very difficult to weld an angle-iron ring." Others say "It is not practical."

The steam-force which should be resisted by the portion of the shell cut away for the hole is wholly thrown upon the shell at *a*, *b*, for there is very little strength in the curved portion of the flange at *B*, whilst in the joint *A* that force is wholly resisted by the angle-iron, which has plenty of metal in the points most strained.

For the joint *B*, the hole in the shell is generally cut much larger in diameter than that of the inside of the neck, which weakens the shell more than necessary, whilst for the joint *A* the hole is cut equal to that of the neck.

In the Wilt & Son's exploded boiler there were several cracks in the shell radiating from the hole cut for the necks, which proves the greater strain that portion of the boiler had to sustain. These cracks leaked several days before the explosion occurred, and thus indicated the approach of the accident. Explosions are frequently indicated in the same way, and it is explained in "Pocket-Book of Mechanics," page 436, and also in my work on "Steam Engineering," page 87. If these rules were more respected by engineers many boiler explosions could be avoided.

A letter from New York, published in Philadelphia papers August 28th, says: "An explosion occurred this morning on board the steamer *Essex*. The explosion was a mystery. The steam-drum was blown completely off." The mystery was probably the flanged joint *B*. A

similar explosion occurred on the excursion steamer *Alaska*, near the mouth of Detroit River, September 5th, by which many lives were lost.

The two new boilers made for Wilt & Son are constructed upon nearly the same principle as that of the exploded one, which had three necks, 12 inches diameter, connecting the first steam-drum with the main shell, and two necks between the first and second steam-drums. The two new boilers have each two necks 16 inches in diameter, with 18 inch holes in the shell.

Suppose the steam pressure in the boiler to be 100 pounds to the square inch, the force on the joint *B* will then be $201\cdot06 \times 100 = 20,106$ pounds, or nearly 10 tons to be borne by 30 rivets of eleven-sixteenth of an inch in diameter, or 670·2 pounds the tensile strain on each rivet, or 1800 pounds to the square inch. If this force was applied evenly on the rivets the danger would not be so great, but the treachery of the joint *B* is that the greatest part of that force acts on one side of the rivets.

The diameter of the shell is about 54 inches, and $54 \times 18 \times 100 \times \frac{1}{2} = 48,600$ pounds, the shearing force acting on 14 rivets, or 3471·4 pounds on each rivet in the flange. The force, 48,000 pounds, is acting on the shell and flange at *b b'*, where there is acting the additional force of the usual steam pressure in the boiler, namely, $54 \times 100 \times \frac{1}{2} \times \frac{5}{16} = 8640$ pounds per square inch of section of the shell.

The joint *B* is therefore the weakest part of the boiler, and is the principal cause of explosions of this class of boilers.

It is an overlooked fact that the quality of workmanship in the neck-joint *B* is generally inferior to that of the rest of the boiler. The height of the conical riveted heads in the shell varies between $\frac{7}{16}$ and $\frac{1\cdot0}{16}$ of an inch, whilst in the neck-joints that height is generally only $\frac{4}{16}$ to $\frac{5}{16}$, and very often less.

The principal strain on the rivets in the shell is a shearing force, whilst the rivets in the neck-joints not only sustain the same or greater shearing force but also a tensile strain, and therefore the riveted heads in the neck ought to be much stronger than those in the main shell.

I beg to be distinctly understood that the remarks here made are not intended to apply specially to the new boilers at the mill of Wilt & Son, but to that class of boilers in general.

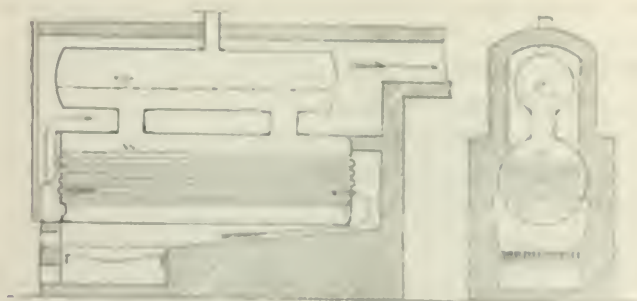
I have lately been entrusted with the inspection of a new set of similar boilers constructed by Mr. Le Van for Mr. George Campbell, at Twenty-first and Washington avenue, and in my report upon the

same laid great stress upon the weakness of the neck-joints, which was fully appreciated by Mr. Campbell, who ordered the necks to be altered to cast-steel plates of half an inch thick, instead of five-sixteenths, in the first necks. This alteration would increase considerably the strength and safety of those boilers; but, unfortunately, the Hartford boiler inspectors object to that thickness on the ground, they say, that "the boilers will be too rigid," probably for difference of shrinkage in the main-shell and steam-drum. The necks are, however, sometimes made of cast-iron, which is still more rigid. The French, Richards & Co.'s boilers, at Tenth and Market streets, also two boilers at Crown and Callowhill streets, have cast-iron necks one inch thick, and are all insured by the Hartford company, but they will not insure boilers with cast steel necks half an inch thick.

The accompanying illustrations, Figs. 3 and 4, represent the boilers in question, but they are not always set as here shown. The water-line is generally kept in the steam-drum at *r*, but in the Campbell, and also in the new Wilt boilers, the water-line is kept at *W* in the main boiler.

FIG. 3.

FIG. 4.



It has been explained that the weakest points in this class of boilers are in the necks, and the force acting to separate the drum and shell is say $F = 40,000$ pounds on the two necks. Suppose the weight of the drum half full of water to be $W = 3000$ pounds. When the neck-joints give way and the boiler explodes, all the water in the boiler and drum is instantly formed into a dense foam of the initial steam pressure, and suppose the force F to act for a time of only $T = \frac{1}{4}$ second. The velocity with which the steam-drum will be thrown upwards will then be

$$V = \frac{gFT}{W} = \frac{32.17 \times 40,000}{3000 \times 2} = 214.4 \text{ feet per second.}$$

The height to which the drum will be thrown vertically will be—

$$H = \frac{V^2}{2g} = \frac{214.4^2}{64.34} = 720 \text{ feet.}$$

It is well known that steam-drums are thrown to great heights and distances by the explosion of this kind of boiler, to which may be referred the following cases at the establishments of I. P. Morris & Co., Philadelphia, 1862; Cornelius & Baker, Philadelphia, 1864; Jessup & Moore, Wilmington, 1871, and Wilt & Son, Philadelphia, 1879. In all these, and in a great many other cases, the boilers exploded on account of weakness of the neck-joints.

The efficiency of boilers of this kind is very deceptive. They apparently evaporate much water, but the steam produced by them is generally very wet, for want of proper circulation of the boiling water, and they are therefore not economical boilers in the consumption of fuel. A thorough scientific investigation of the operation of this kind of boiler would probably make important revelations.

Interoceanic Canals.—One of the most serious objections urged against the probable permanence of the Suez Canal, was based on the assumed impossibility of forming a permanent harbor on an open coast and in the neighborhood of a large river, which emptied in a region where the prevailing winds blow toward the entrance of the canal. M. de Lesseps, however, contrived a dredge in 1875 for removing, at a slight expense, the deposits of sand and mud, which were brought to Port Said by the storms from the west, and for employing them in extending and strengthening the jetties. The results have justified all his anticipations; the deposits have ceased altogether in many places, and the labor of clearing the channel, after the winter storms, has been greatly reduced. M. de Lesseps is now endeavoring to secure an early commencement of the Nicaragua Canal. He says: "In my opinion, it is certain that this useful work will be finished before the end of the nineteenth century, a century which began in war and which will close, thanks to the progress of science, by the pacific opening of new communications among all the nations of the globe."—*Comptes Rendus*. C.

NOTE ON THE CHANGES PRODUCED BY FATTY MATTER
IN THE WROUGHT AND CAST IRON PARTS OF
ENGINES EXPOSED TO THE ACTION OF STEAM.

By M. A. MERCIER,

Chief of the Experimental Laboratory of the Railway Company P. L. M.

Translated from the *Annales des Mines* for 1879, page 234, by Chief Engineer
ISHERWOOD, U. S. Navy.

I have had, on different occasions, to examine in the laboratory some balls, more or less hard, that were taken, from time to time, from the cylinders of steam engines, and which were generally attributed to the use of acid lubricating oil.

These balls, when crushed and digested in ether, left an insoluble residue of peroxide of iron, whilst the soluble part was composed of oleic acid combined with the oxide of iron and mixed with a non-decomposed oil.

Does the formation of this oleate of iron result from the use of oil more or less rancid, having an acid reaction; or, more probable, is it the product of the decomposition of neutral fatty matter in presence of iron and of steam at a high pressure? This alternative caused me to make the following experiment in the laboratory:—

Steam of near the atmospheric pressure was admitted to a closed vessel filled with wrought iron chippings immersed in oil of colza rendered neutral by a previous treatment with carbonate of soda. A gas pipe, dipping into a gauge filled with water, was placed in connection with the closed vessel. The apparatus being purged of air by the steam, I saw small bubbles of gas, which I recognized as hydrogen, disengage—slowly, it is true, but continuously. The same experiment repeated, with wrought iron chippings perfectly free of grease, gave no disengagement of combustible gas.

According to these experiments, and contrary to some explanations given of the changes produced in the metals by fatty matters, the latter have no need of being acid or rancid, nor of being heated above 212°F. , to decompose steam in presence of iron and thus produce oleate of iron, glycerine and hydrogen.

On an examination of the cylinders of the agglomerating engine at

Brassae, after use with an addition of carbonate of soda to the feed-water (which water contained 31·91 grains of sulphate of lime per $1\frac{3}{4}$ pints), the spaces in the piston were found filled with hard matter, formed of grease mixed with oleate of lime and with carbonate of lime, brought in the water, foamed or primed over with the steam. No iron was found; the carbonate of lime had preserved the metal from any change.

The face of the steam-valve of the stationary engine at Valence showed corrosion more or less deep, whilst the valve-stem remained intact. There could be detached from the corroded parts a hard matter which softened at about 392°F., but did not in the least melt. This kind of mastic enclosed particles of iron rubbed off by friction, and had the following composition:

Oil, not changed, ...	2·60
Peroxide of iron, ...	91·55
Oleic acid, ...	5·60
Loss, ...	0·25
	100·00

In this engine there had been no foaming or priming over of lime, which might have, as in the preceding case, preserved the iron from change.

In the stationary engine of the workshops at Paris the same fact occurred. The lubricating oil of the inclined valves collected at the lowest part of the valve-chest and perforated the cast iron.

In the locomotives there was observed the same change in the metal at the tappings for the screws which held the springs of the steam-valve.

These observations led me to make the following experiment: An iron bucket containing wrought iron chippings, thoroughly saturated with oil of colza previously neutralized, was left during eight days in a reservoir supplying steam to several steam hammers. At the expiration of this time there were taken from the bucket about $30\frac{1}{2}$ cubic inches of very thick oil, which flowed with difficulty and emitted an odor similar to what is produced by the action of an acid on iron; the iron was strongly corroded, and the oil—colored to a dark brown and entirely soluble in ether—contained 7 per cent. of the oxide of iron. This oleate of iron oxidized rapidly on contact with air and, like all the minimum salts of iron, gave up some peroxide of iron;

when again placed in contact with iron it attacked the iron and was thus brought back to its first state of saturation. In this manner can be explained the large proportion of non-combined peroxide of iron contained in the matter found on the valve-face of the engine at Valence.

These facts appear to me to clearly explain the corrosions of certain boilers receiving fatty matters brought over from the cylinders by the exhaust steam, or used to lubricate the throttle valve of locomotives.

In locomotives the steam is generally taken from the upper part of the boiler by means of an immersed slide throttle valve; the oil used for lubricating the latter becomes saturated with iron, and being thus made heavier than water sinks to the bottom of the boiler where it attacks the iron plates, forming in them those excavations which are only found when feed-water is used of such purity as not to deposit the lime-scale that in most cases preserves the boilers.

The use of mineral oil, thickened if necessary with wax or paraffine, for the lubrication of moving parts placed in the steam, would be without doubt a good means of preventing changes in the material of such organs.

New Clothing Material.—A Berlin inventor has patented a new kind of cloth, which consists principally or entirely of sponge. The sponges are first thoroughly beaten with a heavy hammer, in order to crush all the mineral and vegetable impurities, so that they can be easily washed out. They are then dried and pared, like a potato, with a sharp knife, the parings being sewed together. The fabric which is thus obtained is free from all the danger which sometimes arises from the absorption of poisonous dyes into the system; it absorbs without checking the perspiration, so as to diminish the danger of taking cold; it is a bad conductor and therefore helps to maintain a uniform surface temperature; it can be more readily cleansed than the ordinary woollen garments; its flexibility diminishes the liability of chafing; the ease with which it can be employed in shoes, stockings, drawers, undershirts, hat linings and other articles of clothing seems likely to make it especially useful as a protection against rheumatic and pulmonary attacks.—*Fortschr. der Zeit.* C.

ZINC VEINS AND WORKS OF LEHIGH VALLEY.

Zinc ore was first discovered in Pennsylvania on the site now occupied by the small village of Friedensville (Village of Peace), in Lehigh county, in 1845. The village stands at the head of the beautiful Saucon Valley, rich in an agricultural sense, and doubly so in minerals—iron and zinc. In 1847 William Theodore Reepper, a resident of Bethlehem, and later Professor of Mineralogy in Lehigh University, from a pure love of science wandered over the spur of the South Mountain, that separates the Saucon Valley from Bethlehem, and was shown by a farmer (Ueberoeth) a mineral that had puzzled the local mineralogists to classify. He pronounced it to be “calamine,” or native carbonate of zinc. This hap-hazard discovery led to the development of the apparently inexhaustible mines that have for more than a quarter of a century supplied the large works of the Lehigh Zinc Company at this place. The works were erected by Maj. Samuel Wetherill, now of Philadelphia, in 1853, for the production of zinc-oxide, in furnaces, by a process of Maj. Wetherill's invention. The works cost \$85,000, and on October 13, 1853, they produced the first zinc-white ever made in America. Maj. Wetherill commenced his experiments as early as 1850, believing that it was possible to substitute the oxide of zinc for white lead for paints. In 1852 he successfully invented his “furnace process.” This, combined with the “bag process” of Richard Jones, Esq., made the matter possible. Before completion, the works were blown down by a tornado, but immediately rebuilt, Charles J. Gilbert, Esq., of New York, being Maj. Wetherill's partner. The works had an annual capacity of 2000 tons. Up to 1857, when Messrs. Gilbert & Wetherill sold out to “the Pennsylvania and Lehigh Zinc Company,” the product had been 4775 tons of oxide. This company was composed of New York capitalists, with a capital of \$1,000,000, and Thomas Andrews, of New York, was the first president. Maj. Wetherill continued in the superintendence of the works until 1857, when he was succeeded by Mr. Joseph Wharton, of Philadelphia. The latter leased the works, and his financial ability and his means and credit floated the concern through the financial storm of 1857. In 1860 the title of the company was changed to the Lehigh Zinc Company, and it is now a strictly Philadelphia company.

These works produced the first *metallic* zinc made in America. Maj. Wetherill had made many experiments looking to the production of metallic zinc, but had been only partially successful. In 1859 Mr. Wharton contracted for the erection of spelter works, and their erection was entrusted to Mr. Louis De Gee, of the firm of De Gee, Gernant et Cie., of Ougree, Belgium, who had been induced to come to the United States for this purpose. These works were put in successful operation, and produced the first metallic zinc in July, 1859. The operatives in this department were at that time imported from Belgium, and importation of Belgian experts and workmen have been frequent since. These spelter works have been in active operation from that time, and during the Franco-Prussian and Turko-Russian war, the European demand upon the works was very large for the manufacture of cartridge cases.

In all that pertains to the original in the application of zinc these works seem to lead. The first sheet zinc, as well as the first spelter, was here made. Under the superintendence of B. C. Webster, Esq., then and since 1863 President of the Company, a mill for the rolling of sheet zinc was erected in 1864 and 1865. Alex. Trippel, who had been sent to Europe to acquaint himself with the production of sheet zinc, had supervision of the erection. The first sheet zinc in America was rolled in these works in April, 1865.

Before describing the mines that supply all these works, and which are a wonder in their way, a brief description of the buildings and the process of manufacture will not be without interest. The old oxide-works include about two acres of buildings, furnaces, tower, dry room, bag room and packing houses. The ore for this purpose is ground fine by a stone crusher, and then carefully mixed with coal known as "buckwheat," next in grade to "pea." It is then transferred to the furnaces, of which there are 54, with 1390 feet of grate surface. Within these the mixed coal and ore is reduced by the direct action of heat and the cold-blast upon a furnace bed having a multiplicity of small holes, each producing the reducing-flame of the blow-pipe. The zinc oxide rises, passes through a huge combustion flue to a large circular tower, 50 feet high, in which the oxide and ashes separate. The ashes being heavier than the oxide, the velocity of the fans which impel the product forward lifts the oxide to the top, and the ashes drop to the bottom. The oxide is forced onward through a cooling-room, size 80 by 40 feet, and heated to from 400 to 700 degrees Fahrenheit.

Thence the oxide is blown through large flues into the "bag" room. This is a huge building, devoid of furniture, excepting long bags of muslin, 45 feet long, in which the oxide is deposited. It is now white as snow, and after being kiln-dried and bolted, it is placed in bags, and by heavy pressure reduced in bulk, barreled, and is ready for shipment.

The spelter furnaces cover a space about one-half that occupied by the oxide department, taken up by rooms for storing ore, grinding-rooms, dry-room for retorts, pottery, reverberatory furnaces and spelter furnaces. Of the latter there are thirty-two. The ore, having been ground and mixed with coal, passes through the reverberatory furnaces. In calcinating it changes from a blue blende to a deep yellow. The sides of the furnaces bristle with retorts. These are charged with the calcined blende, the mouth of each being covered with a fire-clay condenser. An intense heat is maintained by fires beneath, and condensation takes place within the cones. The metal is then drawn out into ladles, poured into iron moulds, forming ingots about $1\frac{1}{2}$ inches deep and 7 by 22 inches in size. When cooled the metal is ready for the sheet-mill or the market.

The rolling-mill is a brick structure 103 by 64 feet. The sheets are heated in ordinary annealing furnaces, and are rolled by ordinary two-high sheet rolls. The secret of polishing the plates consists in rolling numbers of them at a time and changing their position in the "pile," the friction doing the work. As early as 1857 Maj. Wetherill had sent some metal to the sheet-iron mills of the Messrs. Wood, which was successfully rolled and showed the malleability of the metal. The polish was wanting. When Maj. Wetherill first saw the simple process by which the metal was polished—and considered how much thought, time, labor and money he had spent in trying to find the secret—he relieved his mind with a cavalry man's expletive and walked away. The sheets are cut into any size desired, and a recent invention enables the company to cut circular plates for stoves, of which there is a large demand. The American sheet zinc supplies not alone the home market now, but much of it is sent abroad. It is fully up to the standard of the popular "La Vieille Montaigne" of France, and because of its freedom from arsenic and iron is often preferred.

The capacity of these works is as follows: For oxide of zinc, 3000 tons per year; for metallic zinc, 3600 tons per year; for sheet zinc about 3000 casks or 1800 tons, or about one-half the annual consump-

tion of the country. From 300 to 500 men are employed by the company, and 40,000 tons of coal are annually consumed.

All this has grown up from Prof. Roepper's discovery in the Sancer Valley, and it is worth while returning to this point. The mines are four miles away from the works, and all the ore is hauled by heavy teams over the rough mountain roads. The consumption of ore taken from these mines has reached the enormous quantity of 19,000 tons in a single year, including rich blende, which has been developed in the progress of mining. The main shaft is 250 feet deep, and the valley is arched and tunnelled and cut away to a great depth and in a perfect network to get at the seams of the veins.

All about are evidences of a violent upheaval in the long ago, and in the crevices between the rocks the calamine or blende is found, with veins of iron ore at times mixed with the zinc veins. The veins are followed under, over and around huge rocks, which are carefully propped up, and the leads are a perfect labyrinth of rocky-begirt aisles, a wonder to behold, and a rare study for the geologist, the metallurgist and the engineer. But the curiosity of the mines is the monster engine—believed to be the largest and most powerful in the world—and, in honor of the efficient President of the Company, happily named "Webster's Unabridged." At an early day, and at a shallow depth, water was encountered in working these mines. It was overcome by a small pump worked by a single-horse power. Later this was followed by a donkey pump, still used for dressed ores. Then, as the mines went downward, came a Burdon engine of 30-horse power. This was followed in 1863 by a Corliss engine of 100-horse power, working a series of centrifugal pumps, which found their limit at a depth of 65 feet, with 1500 gallons of water per minute. But the water came faster than the pumps could remove, and the company decided to make some lasting provision for controlling it, by establishing power to raise 4000 gallons per minute from a depth of 150 feet, if so much should be found, and to this end they erected and started, in 1865, an engine of 32-inch cylinder and nine feet stroke, working two 22-inch lifting pumps, to which a third 22-inch lift was soon added with 17 strokes per minute, and the shaft carried down to 122 feet in 1866, when it encountered and raised 5600 gallons, and there found the limit of its capacity.

Mr. John West, the engineer of the company, had already matured a plan of engine, pumps and shafts, for raising 12,000 gallons per

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minute from a depth of *three hundred feet*, and in December, 1868, the company contracted with the Messrs. Merrick, of Philadelphia, for this new engine, and a year later with Messrs. I. P. Morris & Co. for the pumps, boilers and mountings. The timber for shaft and pump-rods was brought from Georgia. This engine and its pumping apparatus were set in motion January 19, 1872, in the presence of a large concourse of people and amid interesting ceremonies. A technical description of the engine is not wanted, but the following particulars will not be uninteresting: The engine has a pumping capacity of 17,000 gallons per minute (and has run to 19,000 per minute in an emergency), raising water from a depth of 350 feet. The engine alone weighs 650 tons, and including the pumps and boilers, the total weight of the machinery is 1000 tons. The cylinder is $110\frac{1}{4}$ inches in diameter; length of stroke, 10 feet. The heaviest pieces of iron in the engine are the sections of beams, which weigh 24 tons each. The fly-wheels, of which there are two, weigh 75 tons each; crank-pins, 1 ton each. The piston-rod is 14 inches in diameter. The crosshead weighs 8 tons. The connecting-rods have 9-inch necks, are 15 inches in the middle, 41 feet $2\frac{1}{2}$ inches long, and weigh 11 tons each. There are two air-pumps, 50 inches in diameter each. The engine drives four plunger-pumps, each 30 inches in diameter by 10 feet stroke, and four lifting-pumps, each $31\frac{1}{2}$ inches in diameter by 10 feet stroke, the plunger-pumps being uppermost and stationary. The lifting-pumps are in the bottom, and are movable, so as to go down as the shaft is sunk. To handle these pumps a steam capstan capable of lifting 50 tons vertically is used.

The foundation that holds this moving mass of iron—and it moves without a jar—is a marvel. The bob-wall of solid masonry 9 feet thick was commenced on a plat of solid rock 114 feet below the surface. The foundation for the engine is 32 feet deep below the bed-plate. The engine is estimated at 3500 horse power. The engine is conceded to be the largest fixed single engine in the world, that at Harlaem Meer being a compound engine, with one cylinder within the other. She works comfortably at 12 strokes per minute. Altogether, this engine is a marvel of mechanical engineering and mechanical skill, and it has attracted visitors from all sections of the world.

This monster is now standing idle. Recently the company discovered a new vein of blende, which they are now working without any interference from water. This vein is not only very rich, but has

some very peculiar and very desirable characteristics, being available, when worked with brass or copper, for purposes unknown to ordinary zinc—among others, that of making metallic cartridges. The cost of running the large engine was so great that for a time it was feared these works would have to close up. An advantageous contract and the discovery of the new vein have averted this calamity to South Bethlehem. The works occupy ten acres of ground, and their cost has been as follows: Oxide works, \$125,000; spelter works, \$100,000; rolling mill, \$51,000. Total, \$276,000.—*Public Ledger*.

ALGERIAN IRON ORES. MINES OF AIN-SEDMA, NEAR COLLO.

Translated for the JOURNAL.

Results of analyses made at the School of Mines, Paris, Aug. 21, 1876, by Mons. A. Carnot, Engineer of Mines, Director of the Assay Bureau.

	Samples				
	No. 3.	No. 9.	No. 16.	No. 20.	No. 21.
Silica, ...	5·	2·	2·60	2·	2·30
Alumina, ...	1·60	.....	.....	trace	trace
Peroxide of iron, ...	89·60	99·	96·60	98·	98·60
Oxide of manganese, ...	trace	.....	trace	trace	trace
Lime, . . . . .	.....	0·30	0·20	.....	trace
Magnesia, ...	0·15	0·15	.....	.....	.....
Sulphuric acid, ...	Absent in all the specimens				
Phosphoric acid, ...	0·10	0·05	trace	0·05	0·05
Loss by calcination, ...	3·30	.....	.....	.....	.....
Totals, ...	99·75	101·50	99·40	100·05	100·95
Pure iron, ...	62·12	68·64	66·98	67·95	68·36

Names of the ores:

No. 3 Ledoux bed (micaceous; "*fer oligiste*").

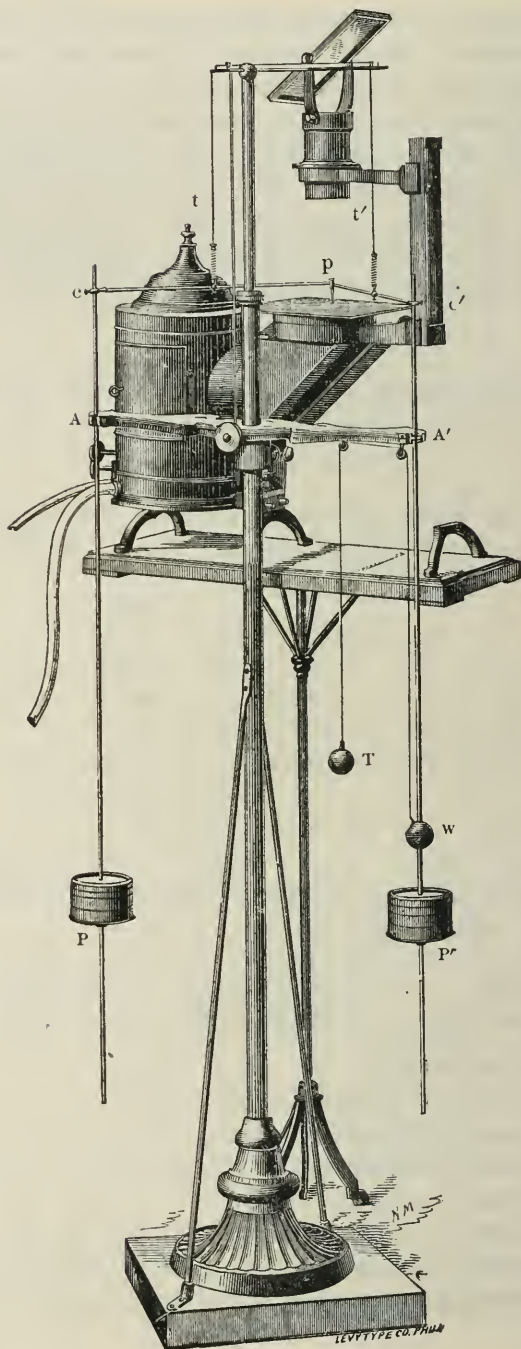
9 Almont Idid (magnetic oxide).

16 Carassa Incline (magnetic oxide).

20 Carassa Level.

21 Laquais.

Nos. 9, 16, 20, 21 contain suboxide of iron (*fer oxydulé*), whence a slight augmentation in the percentage of iron.



QUEEN'S NEW FORM OF TISLEY'S COMPOUND PENDULUM.

The object of this instrument is to trace the elegant curves, corresponding to sonorous vibrations, so well known under the name of Lissajou's figures. With Lissajou's instrument, the figures are only visible while the forks continue to vibrate, and they only give the elementary forms, while the compound pendulum gives us a permanent set of complete tracings, elegant in design and of infinite variety. They can be preserved for years, and studied at leisure.

"This instrument is not limited to certain figures or certain classes of figures. It will trace with equal ease the elegant curves, representing all the musical intervals, and an endless variety of other curious curves, corresponding to the gradual changes between unison and octave, octave and fifth, and generally between the fundamental and its harmonics.

"Besides these changeful phases it may describe others, which have no equivalent in music. In most cases such figures will be extremely complex, but always rigorously symmetrical. By the optical method, the consonance or dissonance, as already stated, is represented by a mere outline; but the compound pendulum, after first tracing this elementary form, fills up the enclosed space with an exact reproduction of the same curve, always in a gradually decreasing scale until the vibrations die away. We have thus a series of curves within curves, which please by their elegant form and marvelous regularity; but the eye, gratified at first, is soon bewildered, and at last is lost in the midst of the apparently endless gyratory web."

This very interesting instrument, in the form presented in the figure, is specially adapted for use with the vertical or upright lantern; it consists of two pendulums, PP' , which conjointly move the pen. The apparatus is simple and easily worked, the two pendulums, PP' , are balanced on knife edges at AA' , and continued above their axis of suspension to cc' , from which points project two brass arms cp and $c'\mu$, which, when the pendulums are quiescent, meet at right angles in p . Perfect freedom of motion in every direction is obtained by connecting these with the pendulums by ball and socket joints at cc' . Two threads, tt' , are fastened at their upper ends to delicate springs, attached

to the brass arms, *cpe'p*, and at their lower ends to an adjustable screw, *d*, by means of which the tracing point, *p*, may be raised and lowered without, in any way, affecting the vibrations of the pendulums.

The brass plates, sliding upon the pendulums, are intended to receive the weights, which can thus be placed at different heights, and the relative rate of vibration of the two pendulums altered. The sum of the weights used should vary from 5 to 12 pounds. *W* is a weight sliding upon its pendulum, and counterpoised by a weight *T*. The object of *W* is to slightly change the rate of vibration while the pendulums are in motion. By this means the pendulums can be adjusted very accurately, or if desired, one can be given a small fraction of a vibration in excess of the other, it can be entirely removed if desired.

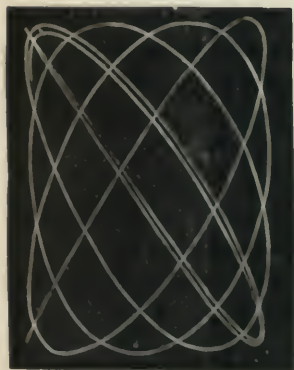
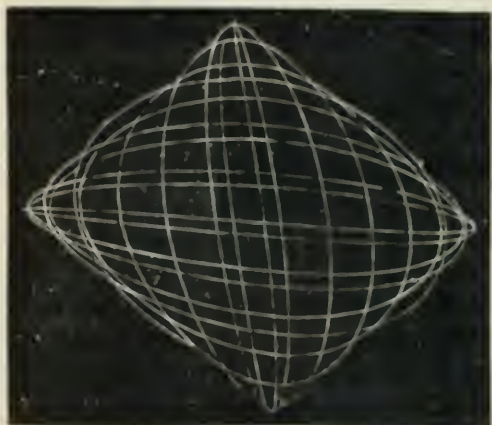
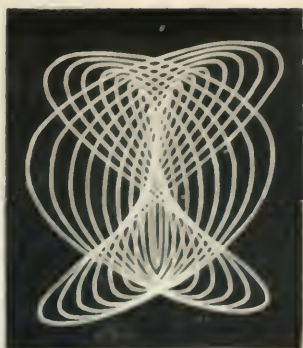
To exhibit these beautiful effects to an audience a plate of glass, blackened by burning camphor, is placed upon the vertical lantern, as shown in the figure, the requisite weights are added to the pendulums and they are set in motion.

Then, if we want a curve corresponding to an octave, one of the pendulums must make two vibrations while the other makes one. Having ascertained this, we start the pendulums together, then lowering the pen, the beautiful curves will be traced.

"It is not easy to imagine a more striking experiment than that afforded in the present instance, by the noiseless and gradually decreasing sweep of a pen point gliding over its sinuous path, in obedience to the oscillations of two conjoined pendulous bodies, and tracing, before the eyes of admiring spectators, curves of maze-like intricacy and yet of faultless symmetry. As in music, the simplest harmony is the most agreeable to the ear, so with these figures, the simpler the proportions between the vibrations of the pendulums the more pleasing are the resulting curves."

Fac-simile copies of tracings made with the new instrument are given. These beautiful tracings can be preserved for years by simply flowing them with collodion. James W. Queen & Co., of Philadelphia, are the manufacturers of this instrument.

Protection of Iron against Rust.—A varnish composed of 120 parts mercury, 10 parts tin, 20 parts green vitriol, 120 parts water, and 15 parts hydrochloric acid of 1·2 sp. gr. furnishes a good coating for iron that is exposed to the weather.—*Oester. Zeitsch.* C.



AMERICAN CERAMIC CLAYS.

The materials for making every description of fictile ware are found widely distributed in the United States. As early as 1766 American clays were imported into England, captains on their return voyages often taking samples from the Carolinas, Georgia and Florida. Many of these reached Wedgwood, who, in allusion to one of them says: "It will require some peculiar management to avoid the difficulties attending the use of it." These trials turned out well, as we find him making arrangements for a regular supply from Ayer, in the country of the Cherokees, about three hundred miles from Charleston. He desired a monopoly by patent or parliamentary grant, but ultimately sent out an agent. In 1768 a cargo of Carolina clay reached Liverpool, and the trade became general in the Cherokee and Pensacola clays, Wedgwood apparently giving the preference to the latter.

America contributed to Cookworthy's invention of porcelain in 1760. In 1745 an American had shown Cookworthy specimens of kaolin and petuntse found in Virginia, and samples of the ware made from them. It is kaolin which is essential to the success of the manufacture. The final practical effect of Mr. Cookworthy's association with the American was the foundation of the English porcelain industry. The acknowledgment is thus made in the catalogue of the Museum of Practical Geology, London: "The great advance of the porcelain manufacture of England is due to the discovery of kaolin in Cornwall, by William Cookworthy, of Plymouth, about 1755. He apparently had his attention directed to the subject by an American, who showed him samples of china stone and kaolin from Virginia in 1745." One hundred and thirty-two years later the country from which the suggestion came is importing kaolin from that which received it.

The clay of Woodbridge was known before the Revolution; the soldiers at Perth Amboy called it fuller's earth and used it for cleaning their buckskin breeches. In 1800 the South Amboy clay was dug for making stone-ware, and after 1812 the use of New Jersey clays for fire-bricks and other refractory materials began. Soon after 1816 Mr. Price was shipping fire-clay from Woodbridge to Boston, to be used in making fire-bricks. In 1820 Mr. Jacob Felt, of Boston, started a trade in the clay, buying it at 25 cents per ton, which trade was main-

tained for years. The Woodbridge deposit is very rich, and is now extensively worked. It can be used for fire and pipe-clay, and for white ware. In 1855 clay for fifty million fire-bricks was taken from the pits at Woodbridge, Perth Amboy and South Amboy, a large quantity being for fine pottery. In 1868 the production had doubled. In 1874 265,000 tons of fire-clay were dug, and an average price of \$3.50 per ton realized \$927,000; 20,000 tons of South Amboy stoneware clay, at \$4 per ton, realized \$80,000—an evidence of the value of the deposit. The term "kaolin" is frequently applied to the native clay as found, before being separated from its impurities. In a report from the secretary of the United States Pottery Association for 1876 he observes that the clay or kaolin mines of the United States have been wonderfully developed in the past few years. Rich and inexhaustible beds exist in the following States: Delaware, three extensive deposits; Pennsylvania, three very fine mines, which are being worked, and the whole of Chester county abounds with as fine a deposit as England can boast; in Illinois, Missouri and Indiana large and rich deposits are being worked; New Jersey abounds with ball clay and all kinds of fire and retort clays, while Maine, Connecticut and Maryland furnish feldspar in abundance, and Pennsylvania and Maryland have endless quantities of quartz or silica. It may appear singular that the Union Porcelain Works at Greenpoint import kaolin; but, as remarked by Charles de Bussy, the decomposition of feldspar *in situ* does not itself serve for the fabrication of porcelain.—*Jour. of App. Science.*

Economy of the "Compound" Engines.—M. A. Leduc collates the comparative experiments of Hirn, Leloutre, Hallauer, Dwelshauvers-Dery and Grossetete with the common system and the Woolf or compound system. The comparisons are made with especial reference to the complicated and injurious effects of the heated walls of the cylinders and of the internal changes in the steam pressure. The great skill of the engineers who conducted the experiments gives great value to the results. Leduc finds ample reason for the great reputation of the compounds among merchants and naval officers in their steadiness of action, their slowness of wear, and their economy of lubrication. Some opponents of the Woolf system lay great stress upon the cost and weight of the machinery, but their objections are soon compensated by the continued economy of fuel and lubrication.

Comptes Rendus. C.

A PECULIAR SPARK DISCHARGE.

When the electrodes of an induction apparatus consist of a point and a ball or plate, the striking distance of the spark produced is considerably greater if the point form the positive pole and the plate the negative, than if the point be negative and the plate positive. With the latter arrangement, under certain conditions, Herr Hankel (of the Leipsic Society of Sciences) has observed the remarkable fact that from the negative point *positive* electricity may pass over in long sparks to the opposite plate.

To the pole of an induction apparatus, which is positive for the break of the current, a blunt point was attached, and opposite to it was fixed a brass disc 200 mm. in diameter, which, with the negative pole of the inductorium, was connected to the earth. With this arrangement there passed, at an interval of 240 mm., zigzag sparks from the point to the plate, while, with greater intervals, a brush discharge took place from the point. The point being then made the negative pole of the inductorium, by turning the commutator (the primary current having the same strength), sparks first passed at an interval of 96 mm. When the point was removed further from the plate there appeared only radiations. The sparks which appeared at 96 mm. interval were zigzag in form, thin, and without much sound, and they continued so till the interval was contracted to 56 mm. Then the spark altered in its nature—it became pretty straight, and produced a more intense sound.

The peculiar aspect of the spark between 96 mm. and 56 mm. interval suggested the idea that positive electricity was carried over, and the insertion of a Holtz funnel tube confirmed this fully. By other means, and directly with the electrometer, it was demonstrated that with an interval between the point and the plate of from 96 mm. to 56 mm., there passed from the point which was negative at the break of the primary current positive electricity, whereas with a less interval of spark, negative electricity passed.

For this interesting phenomenon, which the author intends to study further in its details, he offers the following explanation:

The opening of the circuit of the primary coil at first brings to the point at the so-called negative pole negative electricity. If, now, the

distance of this point from the opposite plate be greater than 96 mm., the negative electricity cannot pass in sparks; but, also, the oscillation which immediately thereon occurs in the induction wire, and which now brings positive electricity to the previously negative point, has not power enough to discharge this positive electricity in sparks, because the tension produced by this backward oscillation (Rückschwingung) is weaker than that produced by the first direct impulse at break of the primary, this being capable of breaking through an interval of 240 mm. When the point at the negative pole is approximated to a distance of 96 mm. to 56 mm. from the plate, still the negative electricity driven to the point by the break of the primary circuit cannot pass over in sparks; but the positive which thereupon comes to the point in the oscillation which then occurs, can do so. Since, however (as already remarked), the tension produced by it is less than that produced through the direct action from the break, the spark is thinner and less powerful than if, with the same interval, the point be made the positive pole by reversing the direction of the primary current. If the negative point be now brought nearer to the plate, to a distance less than 56 mm., the negative electricity brought to it by the break of the primary current can pass in sparks. But by this discharge the following oscillation is so weakened that it does not render luminous the corresponding funnel tube, or does so to a very slight extent.—*English Mechanic.*

THE SUN'S POWER.

In an interesting and eloquent paper on "The Sun a Source of Power," published in the *Scientific American*, Prof. Langley takes the following method of giving some idea of the work performed by the sun's heat on our earth, which receives only a small fraction of the enormous quantity sent out yearly from the centre of our system. Assuming the area of Manhattan Island to be 20 miles and the annual rain-fall 30 inches, he shows by a simple calculation that this small portion of the earth receives 1,393,920,000 cubic feet, or 38,781,600 tons, of rain in a year. "The amount of this," he says, "may be better appreciated by comparison. Thus, the Pyramid of Cheops contains less than 100,000,000 cubic feet and weighs less than 7,000,000 tons; and this water, then, in the form of ice, would many times replace the largest pyramid of Egypt. If we had to cart it away, it would require 3,281,800 cars

carrying 12 tons each to remove it, and these, at an average length of thirty feet to the car, would make six trains, each reaching in one continuous line of cars across the continent, so that the leading locomotive of each train would be at San Francisco before the rear car had left New York." A day's rain-fall of one-tenth of an inch spread over the United States represents ten thousand millions of tons, and would take, he states, more than all the pumping-engines which supply Philadelphia, Chicago, and other large cities dependent more or less on steam for potable water, working day and night for a century, to put it back to the height to which it was raised by the sun before it fell. It has been found by careful experiment that the effect of the heat of a vertical sun in the month of March, acting on a square foot of the earth's surface, after having lost a portion of its energy through absorption by our atmosphere, is equivalent to 0.131 horse-power, and other problems with equally startling results can be readily framed from this and other accessible data.

In "Progress" we find the following short sermon on the power of God evinced in a recent storm: "We have had four to six inches of rain-fall in Philadelphia, and perhaps over the whole area of several States. Let us measure in barrels or tons this vast avalanche, and calculate the amount thus beneficently dispersed. A square foot, covered one inch deep with rain, would, of course, represent one hundred and forty-four cubic inches of water. Now, as one pint contains about twenty-eight cubic inches, one square foot one inch deep contains say five pints. Therefore an acre, covered one inch deep, would need twenty-seven thousand gallons, weighing eight pounds each, or over one hundred tons of water per acre for every one inch of rainfall; sixty-four thousand tons for every square mile; eight million tons for the area of Philadelphia. The silent force of the sun has lifted this enormous aggregate a distance of say one mile high; has carried it suspended in the atmosphere perhaps a thousand miles, and then has precipitated it as the gentle dew, the dashing shower or the thundering rainstorm. Such and so vast are the powers of Nature."

Phosphatic Beds.—Geological explorations have shown the probability that Russia contains beds of phosphate of lime of sufficient extent to supply Europe for an indefinite period. Three companies have already begun to work the deposits.—*Fortech. d. Zeit.* C.

COHNÉ'S ELECTRIC CANDLES.

An improved form of electric candle has been patented by Mr. S. Cohné of 65 Grace-church street, London, for which the following advantages are claimed:

Up to the present time all electric candles in use have been made from pure carbon or carbon mixed with other substances, such, for example, as kaolin or plaster of Paris, all which have the great disadvantage of burning too quickly away and producing, in a greater or lesser degree, a flickering light. Such candles therefore require controlling mechanism to regulate their distance from each other. Mr. Cohné's invention consists in making or forming a candle of ultramarine or the substances which when united together form or produce ultramarine. The ultramarine may be green, blue or of any other color in which it is produced. It may be used either in its pure state or mixed with carbon, kaolin, plaster of Paris, molasses, or with any metal reduced to powder so as to be in a finely divided state. The metal preferred is copper, and it is ultramarine, carbon, powdered copper and molasses that the patentee employs. To about four parts of carbon he adds one part of ultramarine and one part of the finely divided metal and as much molasses as will when mixed with the other materials be sufficient to form the whole into a paste which can be moulded or otherwise formed into the shape desired. The candle thus formed is dried and heated for a sufficient time by fire by whose action all the moisture is evaporated, the sulphur is burned away, and the molasses as well as all other organic matter becomes carbonized. The patentee does not confine himself to the exact proportions named above, and it will be understood that the mixture alluded to is only one of those in which the candle may be made. When these candles are put into use the resistance and the current in the arc are to a very great extent less varying, and controlling mechanism to regulate the distance is nearly unnecessary, because the candle is consumed very slowly in comparison to those heretofore in use. Moreover, less consumption of energy is required for the new candle, and therefore the divisibility of the electric light becomes easier. For effecting the latter purpose, Mr. Cohné bakes the candle in a zinc tube, whereby the zinc of the tube sublimates, and partly enters into the candle. By this means the conductivity is greatly increased; thus very little consumption of energy takes place, and the problem of the divisibility of the electric light approaches solution.—*English Mechanic*.

DIVISIBLE CANNON.

Translated for the JOURNAL.

The Russian artillery have lately adopted a style of cannon entirely new, destined to play an important part in future wars.

This cannon has the peculiarity that it can be divided into two, three or four parts, which may be transported separately, to be united at any place. The moving of it may be very rapid, and the mechanical means employed to maintain the parts in contact assure the perfect solidity of the cannon. We see immediately what services this new system applied to cannon is called upon to render in wars in mountainous countries. Difficulties often insurmountable in the transport of heavy artillery through gorges more or less abrupt have evidently been overcome by this possibility of dividing the total weight of the cannon in a number of parts relatively much lighter. The Russian government, struck with these advantages, wished, on the occasion of the late war in the Balkans, to make a trial of the new engine. The first experiments were made in Russia with a gun of small size, and the results were so satisfactory that the War Department undertook without delay the construction of a divisible cannon of twenty centimetres interior diameter and of a mortar, equally divisible, of twenty-three centimetres. The cannon of twenty centimetres is in four pieces: 1. An interior tube of a weight of 541 kilogrammes; 2. the breach, weighing 2904 kilogrammes; 3. the chase (part of the cannon comprised between the trunnions and the mouth), of a weight of 1826 kilogrammes; 4. The trunnions, weighing 98 kilogrammes. This would make a weight of 5369 kilogrammes in the entire cannon mounted. This piece has served, in company with a similar mortar, in the late Turco-Russian war.

The trials have been so decisive that the government of St. Petersburg has already constructed pieces of even a larger calibre upon the same principle of division.—*Le Propagateur*.

Artificial Asphalt.—V. L. Dagusau heats coal- or wood-tar in a boiler until the water is all evaporated, adds finely powdered marble or limestone that has been previously burnt, stirring in 5 per cent. of iron oxide, silicate of potash, and gypsum, and mixing the whole thoroughly.—*Dingler's Journal*. C.

Portable Gas.—In England portable gas is now sold and delivered like milk. Country residents receive it from the city in copper cylinders.—*Fortsch. d. Zeit.* C.

Krupp's Homogenous Iron.—After a long series of successful experiments Krupp has placed his "Fluss-Eisen" upon the market as a substitute for malleable iron. With a content of about one-tenth of one per cent. of carbon it resembles the best forged iron, but is superior to it. In large forged pieces it has a resistance of from 38 to 42 kilogrammes per square millimetre (54,046·7 to 59,735·8 lbs. per square inch). In sheet iron the tenacity is raised to between 40 and 48 kilogrammes (56,891·3 to 68,269·5 lbs. per square inch), with an elongation of about 25 per cent. and a diminution of 50 per cent. in the section of the experimental bar at the moment of rupture. The price is little higher than that of ordinary iron. The material is specially valuable for shafts, stern-posts, anchors, machinery, and all work which requires welding when it is made of common iron.—*Ann. du Génie Civil.* C.

Courtenay Automatic Whistling Buoys.—After a thorough trial of these buoys in two of the French light-houses, the Ministry purchased them and ordered eight more, on the recommendation of the Light-house Board. The Chamber of Commerce, the pilots and captains who were consulted, all agreed that they were of great service. The only objections that were made to their purchase came from villagers who were annoyed by the noise, and they were conciliated by removing the buoys to a greater distance. The liabilities to wear or damage are very small; the mechanism is remarkably simple; the ball-valves can work for years without need of repairs. The whistle may be injured by collision; this accident has already occurred at Havre, where the channel is furrowed, at all hours of the day and night, by the numerous fishermen who are careless sailors. To guard against a recurrence of this injury the inventor has devised a protective gallery. Wind, ground-swell and moisture, all increase the penetrating power of the whistle, provided they are not excessive. This is probably owing to the increased compression of the air in the sounding chamber. The intervals between the whistles can be graduated as easily as the flashes of revolving lights, so that the different signals cause no confusion when a number of buoys are anchored in the same neighborhood.—*Ann. des Ponts et Chauss.* C.

The Camphor Eddies.—If a small bit of camphor is laid upon water it begins turning and moving about with great rapidity. If a few grains of lycopodium or other light powder have been previously scattered on the water they are drawn towards the camphor by eddies in an inverse direction. These phenomena were observed in 1748 by Romieu, who attributed them to a difference of electricity between the water and the camphor. Subsequent investigators thought they might be due to the camphor vapor striking the water and producing a recoil. M. Cassanajor has resumed the study of the question and adopted the views of Romieu. He instances the following crucial experiment. At the same time that the bits of camphor are thrown upon the water insert a glass rod which has been rubbed with flannel: the motion immediately stops. If the electricity is removed from the rod by rubbing it with tin foil, it loses its power of checking the eddies.—*Les Mondes*. C.

Saharan Railway.—M. Duponchel proposes the construction of a railway across the desert of Sahara, the first section extending from Algiers to Timbuctoo. Soudan, watered by large rivers, bathed by great interior lakes, shaded by magnificent trees, might produce, in unlimited quantities, rice, grain, sugar cane, cotton, indigo, etc. The project of attaching this fertile region to Algeria, Marseilles and France would be more easily carried out than the Pacific Railroad, which was completed in three years, over declivities 1800 metres (11185 miles) high, with immense defensive works, among which are the wooden tunnels which have an aggregate length of not less than 70 kilometres (43497 miles). The entire route was 3080 kilometres (19138 miles), which was somewhat longer than the proposed route, but the difficulties were, perhaps, no greater. The Sahara has a hard, tough soil, and the sand dunes, which are often supposed to cover the whole surface, would not occupy more than a ninth part of it. The dunes may be owing to the disintegration of rocks, under a long-continued solar action, and the distribution of the debris, by the fierce winds of the desert, into scattered hills. Wherever there is a liability for such shifting, it would be necessary to protect the road by wooden sheds, like those on the Pacific Railway.—*Bull. de la Soc. d'Encour.* C.

Glass Lamp-wicks.—Lamp-wicks of spun glass are made in Germany. They supply the petroleum, oil or spirit more regularly, and lamps which are provided with them can be carried about with less danger of going out or of scattering sparks and kindling conflagrations. For equal strength of flame the glass wicks give a clearer and purer light; they have a less unpleasant odor; they consume less fuel; in spirit-lamps they give a more intense heat, with a more quiet and steady flame.—*Fortsch. der Zeit.* C.

New Application of Hydrogen.—E. Commelin has discovered a new industrial application of hydrogen. He places retorts or tubes of metal or refractory earthen-ware in the arch of furnaces or generators, in hot-air apparatus or elsewhere, where they are exposed to a red heat. They are filled with charcoal, coke or cinders, and a small jet of vapor is introduced, which produces, by decomposition and recombination, hydrogen, carbonic oxide and carbonic acid. The apparatus is thus raised to a red heat and steam is obtained without expense. Each tube which contains 25 kilos (55 lbs.) of coke yields, in 10 hours, 100 cubic metres (3531.658 cubic feet) of gas, which is passed into a purifier and thence to a gasometer. Its illuminating power is increased by mixture with the vapor or gas of volatile or solid hydro-carbons, so as to yield, at about one-sixteenth the cost, a whiter and more brilliant flame than that of coal gas.—*La Houille.* C.

Blood of the Lobster.—Harless found copper in the blood of crustaceans, cephalopods and gasteropods. It has long been known that the blood of these three groups of invertebrates changes its color when it is exposed to the air. Jolyet and Regnard concluded that the blood of the crab contains two coloring substances, one blue and the other red. The first is united with the albumen, which, when coagulated by alcohol, has a clear blue tint; the red dye remains in solution in the alcoholic filtrate. Léon Fredericq finds the same principles in the blood of the lobster, but the red contains no metal; it does not change color in oxygen or in a vacuum; it is not always present. The blue seems to be identical with hemocyanine and contains copper. The saline portion of the blood has a composition almost identical with that of the water in which the lobster lives. The hemocyanine easily unites and parts with oxygen and thus acts as a stimulant to respiration, the nutritive function of the blood being confined to the plasma.—*Bull. de l'Acad. Roy. de Belgique.* C.

Incombustible and Impermeable Wood.—M. Folgacci uses the following preparation: Sulphate of zinc, 55 lbs.; potash, 22 lbs.; alum, 44 lbs.; oxide of manganese, 22 lbs.; sulphuric acid of 60°, 22 lbs.; water, 55 lbs. All the solid ingredients are put into a boiler containing the water at 45°C. (113°F.), and as soon as they are dissolved the sulphuric acid is poured in gradually until the mass is completely saturated. The pieces of wood are kept about 5 centimetres (1.97 in.) apart, and after three hours' boiling they are dried in the open air. The natural appearance of the wood is not changed; to whatever heat it is subjected, it resists combustion, the surface being simply covered with a thin charred coating which is easily rubbed off.—*Ann. du Génie Civil.* C.

Water-spouts at Vitry-sur-Seine.—L. V. Meunier describes two simultaneous water-spouts, one of which was very long and slender, resembling a cylindrical ribbon and assuming a kind of S-shape. M. Faye institutes a comparison between them and similar phenomena which were observed in China, in July, 1878, and gives the following explanation, in accordance with his theory. The air which is brought down by the water-spout is usually colder than the lower strata. When the reduction of temperature passes the dew-point of the surrounding air the spout is surrounded by a light cloud which marks its contour. If, in moving, it penetrates layers which are cooler or drier, this vaporous sheath is dissipated; but the cold column still exists, and continues to lash the water or the ground by its lower invisible extremity, so as to form a cloud of drops of water or of dust. At last, when the descending spires, centered upon a vertical axis, are displaced horizontally by the feeble winds prevailing at different heights, the vaporous envelope undulates more or less violently. As the spires have not all the same radius, nor the same temperature, and as they even form distinct helicoidal currents around a common axis, it may happen that only the central spires are cold enough to precipitate the moisture and form a sheath which is much smaller than the entire channel of the whirlwind. [The S form of the vertical column may be due to simultaneous cyclonic and anti-cyclonic influences, like the similar horizontal formation of synchronous anti-cyclonic snow-storms and cyclonic rains which are so often shown upon the weather maps of the United States Signal Service.]—*Comptes Rendus.* C.

New Antiseptic.—A new and very valuable antiseptic has been discovered in Germany. It is a double salt of borate of potassium and sodium, and is made by dissolving in water equal portions chloride of potassium, nitrate of sodium and boracic acid, filtering and evaporating to dryness. It costs about twenty-five cents a pound, and does not give bad taste and properties to foods. Butter may be made from milk kept sweet by it at ordinary temperature for a week. Meat, game, etc., dipped in a weak solution, remain pure for a long time. A piece of meat well rubbed with the salt and laid away two years ago is now in perfectly good condition. Eggs are dipped in a solution; beer and wine are placed in bottles previously rinsed by it, and remain good for long periods.—*Journal of Chemistry.*

Book Notices.

ELEMENTS OF NATURAL PHILOSOPHY. For the use of Schools and Academies. By Edwin J. Houston, A.M., Prof. Physical Geography and Natural Philosophy, Central High School of Philadelphia, etc. Philadelphia: Eldredge & Bro. 1879.

An elementary work of this nature demands as its chief passport to favor that its arrangement shall be logical, and that its presentation of the facts and principles of the science shall be correct, concise, attractive, and free from ambiguity; but these requirements are so seldom fulfilled that while admirable works of a higher class, adapted to the needs of advanced students, are plentiful, the number of really first-class elementary text-books for beginners has always been limited. The reasons for this are not difficult to assign, and they are to be found partly in the disinclination of capable scientific teachers and investigators to descend from the higher regions of the lecture room and laboratory to place themselves *en rapport* with the childish mind, and partly in the real difficulty of its proper accomplishment, for to do it well demands the exercise of a happy faculty which few possess.

In this particular field the author's previous essays have been attended with an unusual share of success. His "Elements of Natural Philosophy," with which we are here especially concerned, has been written in his happiest vein, and it is almost enough to say of it, for the private ear of the teaching fraternity, that it is quite as deserv-

ing of commendation as his "Elements of Physical Geography," which the writer of this had the gratification of commending before it had reached its present measure of popularity.

In the present book the subjects are presented in logical sequence, and while nothing essential has been omitted its size has been confined within convenient limits. The author's language is clear and concise; the examples by which the principles and facts of the science are elucidated are well chosen, and many of the experiments suggested for the same purpose are simple and homely and on these accounts especially valuable in impressing proper conceptions correctly and intelligently upon the beginner's mind.

While all the sub-divisions of the science are well represented that of electricity is deserving of especial notice, from the fact that the author in relegating magnetism to its proper subordinate place as one of the effects of the electrical current, and in treating the subject generally under the divisions "electrical charge" and "current electricity" has greatly simplified it and brought it more closely in harmony with the present state of our knowledge. The final chapter covers briefly the late advances that have been made in this field of investigation, including therein descriptions of the theory and action of galvanoelectric machines, telephone, microphone and phonograph.

The publishers, too, have done their part well, and the paper, letterpress and illustrations are very creditable. W.

RECREATIONS IN ASTRONOMY, With Directions for Practical Experiments and Telescopic Work. By Henry White Warren, D. D., Author of "Sights and Insights; or, Knowledge by Travel," etc. With eighty-three illustrations and maps of stars. 12mo. New York: Harper & Brothers. 1879.

Dr. Warren is well known to many of our readers as a ready and pleasing writer, full of generous enthusiasm for the harmonies of scientific and religious truth, and an amateur astronomer, whose familiar knowledge of the heavenly bodies has often been instructively imparted to circles of admiring listeners. His own extensive reading has been supplemented by assistance from others, for which he especially acknowledges his indebtedness to Professors J. M. Van Vleck, LL.D., Henry Draper, M.D., and Simon Newcomb, LL.D., and to Dr. S. S. White. Great care is manifested, in all parts of the work, to present the latest information in a simple yet picturesque style, with scrupulous

accuracy, and with such judicious avoidance of needless technical explanations as will bring the subject fully within the grasp of ordinary readers. With the belief, strengthened by an experience which entitles it to great weight, that

“—— the undevout astronomer is mad,”

he has written a book of unusual interest, “not only to unravel some of the highest achievements of the human mind, but also to let the heavens declare the glory of the Divine Mind.” Its value is greatly enhanced by beautiful illustrations and admirable typography. C.

ELEMENTS OF MODERN CHEMISTRY. By Adolph Wurtz, Member of the Institute, Honorary Dean and Professor of Chemistry of the faculty of Medicine of Paris, etc., etc. Translated and edited from the fourth French edition by Wm. H. Greene, M.D., formerly Demonstrator of Chemistry in Jefferson Medical College, Philadelphia, etc., etc. 12mo, pp. 687, with 132 illustrations. Philadelphia: J. B. Lippincott & Co.

While manuals of chemistry have not been wanting in number, this book will supply a want which has long been felt by teachers and students, who have had no choice between small and imperfect text-books and volumes whose magnitude is entirely beyond the time that can be allotted to chemistry.

The author introduces the translator as his “friend and former pupil,” and expresses confidence that the translation will be “a faithful or even improved representation of the original work.”

The opening chapter treats of the evident differences in the forms of matter, and clearly defines those differences which it is the province of chemistry to investigate. The laws of definite proportions and equivalents are then explained and naturally developed into the atomic theory, which is sustained by a terse statement and explanation of Gay-Lussac’s law and the laws of specific heat and isomorphism.

A short but lucid chapter on nomenclature and notation follows, after which the metalloids are taken up individually and arranged in classes according to their chemical analyses, the only basis for a rational classification.

After the student has become familiar with the compounds of the metalloids he is initiated into the probable laws of affinity by the study of the theory of atomicity, which most important doctrine is here stated more clearly than in any other book we have seen.

The history of metals individually is preceded by a description of their general properties, an interesting article on alloys and a general consideration of oxides, hydrates, sulphides, chlorides and oxygen salts, each group being individually considered and important characteristics pointed out.

Nearly half of the book is devoted to organic chemistry, and all of the preliminary explanations are condensed into thirty pages; besides these we find pages here and there devoted to the general molecular structure of the amines, organo-metallic compounds, series of fatty acids, glycols, etc., this matter being introduced when the student is fully prepared for it, so that he may not be obliged first to study general formulæ for classes of bodies of which he knows nothing.

The book is fully up to the times and is an exact representation of the science, all facts being viewed in the light of the most recent developments. It is clearly written, and will be welcomed not only by students and teachers but by chemists and others, who have felt the want of such a book.

The paper, press-work and typography is excellent, as might be expected from Lippincott's house.

Franklin Institute.

HALL OF THE INSTITUTE, Sept. 17th, 1879.

The stated meeting was called to order at 8 o'clock P. M., the President, Mr. William P. Tatham, in the chair.

There were present 112 members and 59 visitors.

The minutes of the last meeting were read and approved.

The Actuary presented the minutes of the Board of Managers, and announced that at the last meeting seven persons were elected members of the Institute; and reported also the following donations to the Library:

Specifications. No. 2043, of 1795; No. 53, of 1878.

From the Commissioners of Patents, London, through Mr. Frederick Ransome.

The Pennsylvania Railroad; its Organization, Construction and Management. By James Dredge. London, 1879.

From Frank Thomson, Gen'l Manager Penna. R. R.

Annual Report of the American Institute of New York.

From the Librarian.

Transactions of the American Society of Civil Engineers. No. 53.

From the Society.

Ninth and Tenth Reports of Exhibitions of the Massachusetts Charitable Mechanic Association.

From the Association.

American Naturalist. 4 Nos.

From the Boston Medical Association.

Boston Journal of Chemistry. 7 Nos.

From the Publishers.

American Architect and Building News. Vols. 1 and 2.

From J. R. Osgood & Co., Publishers.

Quarterly Report of the Chief of the Bureau of Statistics.

From the Chief of Bureau.

Annual Report of the Trustees of the Metropolitan Museum of Art.

From the Association.

Circulars of Information of the Bureau of Education. No. 2.

From the Bureau.

Report on a Preliminary Investigation of the Properties of the Copper-tin Alloys.

From R. H. Thurston.

Annual Report of the Commissioner of Patents, with Index for 1878.

Specifications and Drawings of Patents for March and April, 1879.

From the Patent Office.

Report of the Board of Health of the City and Port of Philadelphia to the Mayor.

From Geo. E. Chambers, Registrar.

Papers read before the Eleventh and Twelfth Annual Conventions of the American Institute of Architects, held in Boston and New York.

From A. Williams & Co., Publishers.

General Index of the Agricultural Reports of the Patent Office, for twenty-five years, from 1837 to 1861; and of the Department of Agriculture for fifteen years, from 1862 to 1876. Washington, 1879.

From the Commissioner of Agriculture.

Silk Goods of America: A Brief Account of the Recent Improvements and Advances of Silk Manufacture in the United States. By W. C. Wyckoff.

From Horstmann & Co., Philadelphia.

Sheet Metal Builder. An illustrated Monthly devoted to the use of Sheet Metal in Architecture. Vols. 1 and 2.

From Dr. W. H. Wahl.

Charter, By-Laws, Regulations and List of Members of the Institution of Civil Engineers. London.

From the Institution.

List of Premiums of the Twenty-sixth Annual Exhibition of the Pennsylvania State Agricultural Society. From the Society.

Annual Report of the Managers of the State Lunatic Asylum, Utica, N. Y. From the Managers.

Report of the Board of Experts on the Test Trial of the Warden Compound Pumping Engine to the Board of City Commissioners of Cincinnati Water Works, March 1879. From J. W. Hill.

Contributions to our Knowledge of the Meteorology of the Arctic Regions. Part I.

From the Meteorological Committee of the Royal Society.

Annual Report of the Chief of the Water Department of the City of Philadelphia. From W. H. McFadden, Chief Engineer.

Annual Report of the Chief Signal Officer to the Secretary of War. From the Chief Signal Officer.

Fourth Annual Report of the State Board of Health of Massachusetts. From Dr. Bringham, Boston, Mass.

Official Army Register. From the Secretary of War.

On Magnets. By O. A. L. Pihl. Christiania.

Die Lehre des Ammonius Sakkas. Von Dr. G. V. Lyng.

Om Forholdet i Middelalderen Mellem den Norske Mark, solv og den Stedse Forringede Gangbare Myntmark, etc. Af C. J. Schive.

Philosophische Studien. Von Dr. G. Willi. Lyng.

Lettre à M. Ernest de Sauley.

Om Advokat Sandons Affære. Af O. Sandberg.

Bemærkninger om Tilregnelighed (Strafskyld) og Sindssygdом, etc. Af Prof. Dr. Faye.

Nogle Oplysninger om Forholdet mellem Ægteskaber og Fødsler med særligt Kendsyn til Ægteskabernes Sliftelsestid. Af Bureauchef Kier.

Om Poncelet's Betydning for Geometrien, etc. Af Elling Holst.

Carte du Royaume de Norvège.

Carte Norge, Sverige og Danmark.

Rune-Indskriften paa Ringen i Forsa Kirke i Nordre Helsingland. Udgivet og tolket af Sophus Bugge.

Om Skuringsmærker, Glacialformationen og Terrasser, samt om Grundfjeldets og Sparagmittfjeldets Mægtighed i Norge. 1. Grundfjeldet. Af Prof. Theodor Kjerulf. 2. Sparagmittfjeldet.

Om Stratifikationens Spor. Af Dr. Theodor Kjerulf.

I Anledning af Schopenhauers af det Thronhjemske Videnskabs-selskab belønnede Pries. Afhandling om den Frie Villies Forhold til Selvlevidstheden. Af M. J. Monrad.

From the University of Christiania.

Dr. Robert Grimshaw read a paper on "Cork Utilization," which was discussed by Messrs. Nystrom and Orr.

Mr. Carbutt read a paper on Heliography, and made some practical remarks on the process, at the same time exhibiting a number of beautiful specimens of the work and its varied application in the arts.

The Secretary read a paper giving an account, as far as has been made known to the public, of the "Autoplate" of Louis Brown & Co., and a number of specimens of the work were exhibited, also some large "Photo-gravures" of Goupil & Co., supposed to be made in a similar manner to the Autoplate, and kindly loaned for the occasion by Messrs. Earle & Son.

Mr. Joseph J. Walton exhibited Queen's new form of Tisley's Compound Pendulum for the first time to a public audience in Philadelphia, and a number of beautiful curves, corresponding to sonorous vibrations, so well known under the name of Lissajous' figures, were thrown upon the screen.

The Secretary's report included accounts of Dickson's process of engraving blocks in hard rubber; Barthelet's Duplicator for producing a number of copies of any writing, drawing or music; the Columbia Bicycle, as manufactured by the Pope Manufacturing Co., with the Cyclometer for indicating the distance traveled; also the Lantern, Alarm Bell, Saddle Bag, etc.; Portable Wash-stands, giving an instantaneous flow of water without connections with the city supply; Nichol's Acid Syphon Pumps; Cooper's plan for reference books; Denison's Patent Reference Index; Lever's method for wire-sewing books; Hoyt's Indestructible Binding; Ferree's Binder for magazines, pamphlets, etc.; Creswell's Double-hinged Open Link; R. & J. Beck's Economic Microscopes, monocular and binocular; Godley's Patent Improved Loose Wheel for Railroad Cars; Pohl's Adjustable Metallic Awning; Nystrom's Metallic Thermometer for ascertaining the temperature of steam; Schutte & Goehring's Water Jet Vacuum Pump for laboratory use; I. Newton Peirce's Patent Portable Boiler Covering; Rebounding lock principle, as applied to the Smith and Wesson Revolver, and an exhibit of the various products of the Health Food Company of New York.

Mr. John W. Nystrom read a paper upon the cause of steam boiler explosions, and illustrated it by drawings on the blackboard.

On motion, the meeting adjourned.

ISAAC NORRIS, M.D., *Secretary pro tem.*

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A GENERAL DIFFERENTIAL EQUATION IN THE THEORY OF THE DEFORMATION OF SURFACES.

By THOMAS CRAIG, U. S. Coast and Geodetic Survey.

The labors of many geometers, notable among whom are Lagrange and Gauss, have brought to a high state of perfection and generality the theory of the orthomorphic representation of one surface upon another.

Lagrange's memoirs, two in number, are contained in the "Mémoires de l'Académie des Sciences," of Berlin, for 1779. Lagrange here gives the most general theory of orthomorphic projection consistent with the condition that all parallels and meridians shall be projected in circles.

Gauss's memoir was more general in its nature than that of Lagrange, although he regretted the necessity which he was under of confining himself to the simpler cases of map construction, and expressed the hope that at a future time the investigation would be resumed; but it never was again studied by Gauss, so far as we can judge from his published papers.

Neither of these great mathematicians seems to have given any attention to another phase of the general problem of representing one surface upon another, viz., by actual development deforming the given surface until it coincides with the surface of projection, or surface upon

which it is desired to represent the given surface. The principle of development is the base of many valuable methods of projection, notable among which is the polyconic projection used in the office of the U. S. Coast and Geodetic Survey; these methods are all well known to those who are interested in this subject, so nothing further need be said of them here.

The immediate object of the following very brief paper is to determine the general differential equation of all surfaces which may be developed, or deformed, upon any given surface.

The idea of obtaining such an equation is not new, though I have only seen it referred to in one place, but the following investigation and its results I believe to be quite new.

M. E. Bour wrote a most valuable memoir upon the subject, entitled "*Théorie de la déformation des Surfaces*," published in the "*Journal de l'Ecole Polytechnique*," Vol. 22. In the beginning of the paper, however, M. Bour expressly states that he will not give the general solution of the problem, and in fact confines himself to the case where the quantities E and G of the text are $= 0$, and also uses the variables

$$\begin{aligned}x &= p + i q, \\y &= p - i q.\end{aligned}$$

It is a well-known fact, that, if we have given the equation of any surface in rectangular rectilinear co-ordinates, we may, by means of this equation, express the three co-ordinates of any point of this surface as functions of two independent variable parameters, say p and q ; and that, conversely, if the co-ordinates x, y, z are thus expressed as functions of the two parameters, these expressions determine the surface; viz., by elimination of the parameters we obtain the equation $f(x, y, z) = 0$ of the surface.

We may, as is customary, of course consider the parameters p and q so determined that the equations of the two sets of lines of curvature shall be

$$\begin{cases} f = \text{const.}, \\ p = \text{const.}, \end{cases} \quad \begin{cases} f = \text{const.}, \\ q = \text{const.}, \end{cases}$$

that is, we may regard

$$f = \text{const.}, p = \text{const.}, q = \text{const.}$$

as the equations of these orthogonal surfaces.

The expression for the element of length on the given surface is

$$1 \quad ds^2 = E dp^2 + 2F dp dq + G dq^2$$

where

$$E = \left(\frac{dx}{dp} \right)^2 + \left(\frac{dy}{dp} \right)^2 + \left(\frac{dz}{dp} \right)^2,$$

$$2 \quad F = \left(\frac{dx}{dp} \frac{dx}{dq} \right) + \left(\frac{dy}{dp} \frac{dy}{dq} \right) + \left(\frac{dz}{dp} \frac{dz}{dq} \right),$$

$$G = \left(\frac{dx}{dq} \right)^2 + \left(\frac{dy}{dq} \right)^2 + \left(\frac{dz}{dq} \right)^2.$$

Now suppose a second surface to exist which is susceptible of development upon the first. Call ξ, η, ζ the co-ordinates of any point and $d\sigma$ the element of length in this case.

If this second surface can be developed upon the first it will be necessary and sufficient that the points of the one be made to correspond to those of the other, that we shall have $ds = d\sigma$ in every direction around two corresponding points.

This equality must hold, then, whatever be the values of dp and dq , which define these different directions.

Now, for $d\sigma$ we have

$$d\sigma^2 = E^1 dp^2 + 2F^1 dp dq + G^1 dq^2$$

and for $d\sigma = ds$ we must have

$$E = E^1, F = F^1, G = G^1.$$

It follows from this that the three new variables ξ, η, ζ are three functions of p and q , such that, being substituted for x, y, z in equations 2, these equations shall be identically satisfied.

Conversely, every solution of equations 2 will furnish a surface which may be developed upon the given surface. It is only necessary to eliminate from these equations any two of the quantities x, y, z in order to find the desired equation which will be the resulting differential equation satisfied by the remaining quantity, say by z . We have, now, from the first and third of 2

$$3 \quad \left(\frac{dx}{dp} \right)^2 + \left(\frac{dy}{dp} \right)^2 = E - \left(\frac{dz}{dp} \right)^2,$$

$$\left(\frac{dx}{dq} \right)^2 + \left(\frac{dy}{dq} \right)^2 = G - \left(\frac{dz}{dq} \right)^2.$$

For convenience write

$$a^2 = E - \left(\frac{dz}{dp} \right)^2,$$

4

$$\beta^2 = G - \left(\frac{dz}{dq}\right)^2;$$

then we may replace these two equations by the four

$$\frac{dx}{dp} = \alpha \cos.\theta, \quad \frac{dx}{dq} = \beta \cos.\varphi,$$

5

$$\frac{dy}{dp} = \alpha \sin.\theta, \quad \frac{dy}{dq} = \beta \sin.\varphi.$$

The second of 2 now becomes

$$\alpha\beta (\cos.\theta \cos.\varphi + \sin.\theta \sin.\varphi) = F - \frac{dz}{dp} \frac{dz}{dq} = \gamma\alpha\beta.$$

or

$$\text{Cos.}(\varphi - \theta) = \gamma.$$

Differentiating the equations of the first row of 5 for q and p , respectively, and subtracting, we eliminate α , the same operations performed upon the second row eliminate y ; we have then

$$\frac{d\alpha}{dq} \cos.\theta - \alpha \sin.\theta \frac{d\theta}{dq} - \frac{d\beta}{dp} \cos.\theta + \beta \sin.\theta \frac{d\theta}{dp} = 0,$$

7

$$\frac{d\alpha}{dq} \sin.\theta + \alpha \cos.\theta \frac{d\theta}{dq} - \frac{d\beta}{dp} \sin.\theta + \beta \cos.\theta \frac{d\theta}{dp} = 0.$$

Multiply the first of these by $\cos.\theta$, the second by $\sin.\theta$ and add; then multiply the first by $\cos.\varphi$ and the second by $\sin.\varphi$ and add; we have then

$$\frac{d\alpha}{dq} - \frac{d\beta}{dp} \cos.(\varphi - \theta) + \beta \frac{d\varphi}{dp} \sin.(\varphi - \theta) = 0,$$

8

$$\frac{d\alpha}{dq} \cos.(\varphi - \theta) + \alpha \frac{d\theta}{dq} \sin.(\varphi - \theta) - \frac{d\beta}{dp} = 0,$$

or

$$\text{Sin.}(\varphi - \theta) \frac{d\varphi}{dp} = \frac{1}{\beta} \left[\gamma \frac{d\beta}{dp} - \frac{d\alpha}{dq} \right], = \lambda$$

9

$$\text{Sin.}(\varphi - \theta) \frac{d\theta}{dq} = \frac{1}{\alpha} \left[\frac{d\beta}{dp} - \gamma \frac{d\alpha}{dq} \right], = \mu$$

For brevity we may also write

$$\text{Sin.}(\varphi - \theta) = \tau$$

then, since $\cos.(\varphi - \theta) = \gamma$, $\tau^2 = 1 - \gamma^2$. Equations 9 are now written

$$10 \quad \frac{d\varphi}{dp} = \frac{\lambda}{\tau},$$

$$\frac{d\theta}{dq} = \frac{\mu}{\tau}.$$

From the expression $\cos. (\varphi - \theta) = \gamma$ we have by differentiation

$$11 \quad \frac{d\varphi}{dq} = \frac{1}{\tau} \left(\mu - \frac{d\gamma}{dq} \right),$$

$$\frac{d\theta}{dp} = \frac{1}{\tau} \left(\lambda - \frac{d\gamma}{dp} \right).$$

Finally, form the expressions for $\frac{d^2\varphi}{dpdq}$ from 10 and 11, and equate the results

$$12 \quad \frac{1}{\tau} \frac{d\lambda}{dq} - \frac{\lambda}{\tau^2} \frac{d\tau}{dq} = \frac{1}{\tau} \left(\frac{d\mu}{dp} - \frac{d^2\gamma}{dpdq} \right) - \frac{1}{\tau^2} \left(d\mu - \frac{d\gamma}{dq} \right) \frac{d\tau}{dq}.$$

From the relation $1 - \gamma^2 = \tau^2$ we have

$$13 \quad \tau \frac{d\tau}{dp} = -\gamma \frac{d\gamma}{dp},$$

$$\tau \frac{d\tau}{dq} = -\gamma \frac{d\gamma}{dq}.$$

Equation 12 now becomes

$$14 \quad \left(\frac{d\lambda}{dq} - \frac{d\mu}{dp} + \frac{d^2\gamma}{dpdq} \right) (1 - \gamma^2) - \gamma \left(\lambda \frac{d\gamma}{dq} - \mu \frac{d\gamma}{dp} + \frac{d\gamma}{dp} \frac{d\gamma}{dq} \right) = 0$$

which contains only E, F, G and the differential coefficients of these quantities and z with respect to p and q , and is consequently the differential equation sought.

Denote now by k the Gaussian measure of curvature given by the expression

$$15 \quad -2V^2k = V^3 \left\{ \frac{d}{dp} \left[\frac{1}{V} \left(\frac{dF}{dq} - \frac{dG}{dp} \right) \right] + \frac{d}{dq} \left[\frac{1}{V} \left(\frac{dF}{dp} - \frac{dE}{dq} \right) \right] \right\} - V^3\Gamma,$$

where $V^2 = E \cdot G - F^2$ and Γ denotes the determinant

$$\begin{vmatrix} E & G & F \\ \frac{dE}{dp} & \frac{dG}{dp} & \frac{dF}{dp} \\ \frac{dE}{dq} & \frac{dG}{dq} & \frac{dF}{dq} \end{vmatrix}$$

Again, denote for brevity the minors of this determinant corresponding to any element by placing that element in brackets, thus,

$$[E] = \frac{dG}{dp} \frac{dF}{dq} - \frac{dG}{dq} \frac{dF}{dp} \text{ etc.};$$

also write

$$A = \frac{dG}{dp} - 2 \frac{dF}{dq},$$

$$B = \frac{dE}{dq} - 2 \frac{dF}{dp},$$

Substituting now in 14 the values of $\lambda, \mu, \tau, \gamma, \alpha, \beta$ we find, after some rather tedious but not difficult reductions, the following form for this equation

$$\begin{aligned} & 4V^2(rt-s^2) + \left\{ 4G\sqrt{G} \left(\frac{d\sqrt{G}}{dp} - \frac{d}{dq\sqrt{G}} \right) \frac{dz}{dp} - \left(E \frac{dG}{dq} + A F \right) \frac{dz}{dq} \right\} r \\ & + 4 \left(G \frac{dE}{dq} \frac{dz}{dp} + E \frac{dG}{dp} \frac{dz}{dq} \right) s + \left\{ 4E\sqrt{E} \left(\frac{d\sqrt{E}}{dq} - \frac{d}{dp\sqrt{E}} \right) \frac{dz}{dq} - \left(G \frac{dE}{dp} + BF \right) \frac{dz}{dp} \right\} t \\ 16 \quad & + \left\{ 2\sqrt{G} \left[\frac{d}{dp} \sqrt{G} \frac{dE}{dq} - G \frac{d}{dp} \frac{A}{\sqrt{G}} \right] + 2[E] \right\} \left(\frac{dz}{dp} \right)^2 \\ & + \left\{ F\sqrt{F} \left[\frac{d}{dp} \frac{4A}{\sqrt{F}} + \frac{d}{dq} \frac{4}{\sqrt{F}} \frac{dE}{dq} \right] + 2[F] \right\} \frac{dz}{dp} \frac{dz}{dq} \\ & + \left\{ 2\sqrt{E} \left[\frac{d}{dp} \sqrt{E} \frac{dG}{dp} - E \frac{d}{dq} \frac{B}{\sqrt{E}} \right] + 2[G] \right\} \left(\frac{dz}{dq} \right)^2 - 2V^4 k = 0 \end{aligned}$$

where r, s, t denote respectively the second derivatives

$$\frac{d^2 z}{dp^2}, \quad \frac{d^2 z}{dp dq}, \quad \frac{d^2 z}{dq^2}.$$

It is to be observed that this equation is linear in $(rs-t^2)$ and in r, s

and t , and is in fact a partial differential equation of the second order of the form

$$Rr + Ss + Tt + V(rs - t) = W,$$

when R, S, T, V and W are given functions of $x, y, z, \frac{dz}{dp}, \frac{dz}{dq}$ or of $p, q, \frac{dz}{dp}, \frac{dz}{dq}$. A general integration is of course impossible, so we will note only a few special cases. If we consider now that the three surfaces f, p, q are orthogonal, then the curves given briefly as $p = \text{const.}$ $q = \text{const.}$ cut at right angles, since they belong to the two different lines of curvature, and for this case $F = 0$ and equation 16 takes the form

$$\begin{aligned} 17 \quad & 4E^2G(rt - s^2) + \left(\frac{dG^2}{dp} \frac{dz}{dp} - E \frac{dG}{dq} \frac{dz}{dq} \right) r + 4 \left(G \frac{dE}{dq} \frac{dz}{dp} - E \frac{dG}{dp} \frac{dz}{dq} \right) s \\ & + \left(\frac{dE^2}{dq} \frac{dz}{dq} - G \frac{dE}{dp} \frac{dz}{dp} \right) t - 2 \left[G \left[\frac{d}{dq} \frac{1}{G} - G \frac{dE}{dq} - G \frac{d}{dq} \frac{1}{G} \frac{dG}{dp} \right] \right. \\ & \quad \left. \left(\frac{dz}{dp} \right)^2 \right. \\ & \quad \left. + [E] \frac{dz}{dp} \frac{dz}{dq} - 2 \left[E \left[\frac{d}{dp} \frac{1}{E} - E \frac{dG}{dp} - E \frac{d}{dp} \frac{1}{E} \frac{dE}{dq} \right] \left(\frac{dz}{dq} \right)^2 - \right. \right. \\ & \quad \left. \left. 2E^2G^2k = 0 \right] \right. \end{aligned}$$

where

$$k_0 = -\frac{1}{2} \left\{ \frac{d}{dp} \frac{1}{E} \frac{dG}{dq} - \frac{d}{dq} \frac{1}{E} \frac{dE}{dp} \right\}$$

For $E = G$ this becomes

$$\begin{aligned} 18 \quad & 4E^2(rt - s^2) + \frac{dE^2}{dp} \left[\frac{dz}{dp} \left(r - \frac{1}{2}t \right) + \frac{2dz}{dq} s \right] + \frac{dE^2}{dq} \left[\frac{dz}{dq} \left(t - \frac{1}{2}r \right) + \frac{2dz}{dp} s \right] + \\ & \left\{ \frac{1}{2} \frac{d^2E^2}{dq^2} - E \frac{d^2E}{dq^2} - E^2 \frac{d^2 \log E}{dp^2} \right\} \left(\frac{dz}{dp} \right)^2 - \left\{ \frac{1}{2} \frac{d^2E^2}{dp^2} - E \frac{d^2E}{dp^2} - \right. \\ & \quad \left. E^2 \frac{d^2 \log E}{dq^2} \right\} \left(\frac{dz}{dq} \right)^2 - 2E^2 \left(\frac{d^2}{dp^2} - \frac{d^2}{dq^2} \right) \log E = 0. \end{aligned}$$

Suppose in equation 16 that $E = G = 0$; this requires that the quantities denoted by α and β shall be imaginary—or

$$\alpha = i\alpha^1, \quad \beta = i\beta^1,$$

it would be convenient in starting from this hypothesis to use the imaginary variables already defined as

$$\begin{aligned} x &= p + i q, \\ y &= p - i q, \end{aligned}$$

however it is not the intention to dwell on this point as Bour's memoir treats the case so fully. The form which the general differential equation assumes in this case is, however, noteworthy. Assume $F = 2\Phi$, then we have

$$19 \quad (rt-s^2) - \frac{1}{\Phi} \frac{d\Phi}{dq} \frac{dz}{dq} r - \frac{1}{\Phi} \frac{d\Phi}{dp} \frac{dz}{dp} t \\ + \left[2 \frac{1}{\Phi} \left(\frac{d^2\Phi}{dp dq} - \frac{1}{\Phi} \frac{d\Phi}{dp} \frac{d\Phi}{dq} \right) \right] \frac{dz}{dp} \frac{dz}{dq} + 2 \left[\frac{1}{\Phi} \frac{d\Phi}{dp} \frac{d\Phi}{dq} - \frac{d^2\Phi}{dp dq} \right] \\ = 0;$$

add and subtract

$$\frac{1}{\Phi^2} \frac{d\Phi}{dp} \frac{d\Phi}{dq} \frac{dz}{dp} \frac{dz}{dq}$$

and this becomes readily

$$20 \quad 2 \left(\frac{dz}{dp} \frac{dz}{dq} - \Phi \right) \frac{d^2 \log. \Phi}{dp dq} - s^2 \\ + \left(r - \frac{dz}{dp} \frac{d \log. \Phi}{dp} \right) \left(t - \frac{dz}{dq} \frac{d \log. \Phi}{dq} \right) = 0.$$

Make in this equation

$$\frac{dz}{dp} \frac{dz}{dq} = \Phi$$

and we find that the equation is satisfied, therefore

$$\frac{dz}{dp} \frac{dz}{dq} = \Phi$$

is a singular solution of the differential equation.

If we make $E = 1$, $F = 0$ and G a function of p only, we come to the case of the development upon surfaces of revolution, a particular case of which has been studied by Weingarten in Vol. 59 of "Crelle's Journal." There are several other suppositions which might be made, and which would conduct to interesting results, but the object of the investigation has been attained, and so I leave the subject here. I think it quite possible that a singular solution might be found for equation 16 (or equation 17, which is a sufficiently general form), which would prove valuable in studying the general geometric proportions of this class of surfaces.

It is to be observed that for E , F , G constant (including the case of $F = 0$) 16 reduces to

$$rt - s^2 = 0$$

the simplest class of developable surfaces, viz., those which can be developed upon a plane.

Washington, D. C., August 24, 1879.

FUTURE WATER SUPPLY OF PHILADELPHIA.

By HENRY P. M. BIRKINBINE, M. E.Read before the Franklin Institute at its meeting October 15th, 1879.

I have had the honor of reading two papers before the Institute upon the "Future Water Supply of Philadelphia." * In the first paper some of the available sources were examined: the Schuylkill, Delaware and the Perkiomen; their volume and the present and prospective comparative purity of the water compared. In the second paper the means now used and those proposed for securing a supply from these sources were presented and analyzed.

It was, no doubt, evident to those who heard these papers, or who have read them, that one object in presenting them before the Institute was to demonstrate the practicability and desirableness of securing a supply of water for the city of Philadelphia from the Perkiomen by gravitation, a project reported upon and recommended to the Councils of Philadelphia in 1866.

I have been requested to read another paper upon this important subject. The request has, no doubt, been prompted by the interest created by several articles in the daily papers and the able article upon the "Future Water Supply of Philadelphia," by James F. Smith, C. E., in the last number of the JOURNAL (October).

After waiting so many years it is a source of gratification to have the public endorsement of this project by an engineer of the standing and long experience of James F. Smith, C. E., whose duties as the engineer of the Schuylkill Navigation Company have made him personally acquainted with this particular region and with the storage and supply of water from streams in the drainage area of the Schuylkill.

While the Commission of Engineers, appointed in 1873 to report upon a better supply of water for Philadelphia, gave the Perkiomen gravity plan their unanimous approval, they suggested so many other plans that it is hard to decide what they did or meant to recommend by their report.

I fully acknowledge my obligations to Mr. Smith personally, and as

* See JOURNAL OF THE FRANKLIN INSTITUTE for May and July, 1878.

a citizen of Philadelphia, for the great amount of care and attention he has bestowed upon the consideration of this important subject, and the valuable information given to the public in his article. Statements made by an engineer of his standing and experience will be accepted without question, as they should be; and yet there may be facts in connection with the subject which have not come under his notice, or conclusions, based upon the representations of others, which may be incorrect. It is for the purpose of making some explanations and adding a few additional facts that this paper is presented for your consideration.

In the water supply of a city the head under which the water should be furnished, and the quantity required, are among the most important points to be settled, and this should be done before any work is undertaken. These questions are readily answered by asserting that the greater the head or pressure and the larger the volume the better. This is true in the main, but there are circumstances and conditions which modify and restrict both of these essentials to a practical limit, and the proper head and quantity become, therefore, important subjects of inquiry.

The head or pressure of the Fairmount reservoirs is but 96 feet above city datum, 54 feet above the highest and 84 feet above the lowest grade of the streets, and as these furnish the most densely populated and the business centres of the city, an augmented head would be of great advantage.

After a careful examination of the entire area covered by the city it was found that a reservoir at an elevation of 170 feet would command almost the whole area, and that the parts lying at a greater altitude would necessitate another system of about double this elevation, leaving a few small districts demanding a still greater height. It was therefore decided that a supply furnished at an elevation of 180 feet would meet the requirements of the city better than any other head. This pressure or force would not be too great for the old pipe system and would be sufficient to reach the upper stories of the larger buildings, and would give a more satisfactory supply through the fire hydrants. This being settled, the next question was, how large a supply must be provided to meet the prospective demands of the city—a more difficult one to answer, as no one can predict what the future of this city may be—and if, as some assert, it is destined to become the London of this continent, and its inhabitants counted by millions, it would

require corresponding works. It was thought better to forecast the future by the history of the past. In 1865 it was found that the demand for water had more than doubled in ten years, and was then an average of over 30 million gallons per day; from this it is estimated that 150 million gallons per day would furnish an ample supply for the increase at that rate for at least 25 years, or until the city numbers between two and three million inhabitants. But this rapid increase will scarcely be realized, and it is probable that the above quantity (150,000,000 gallons) will furnish a copious supply for the next half of a century. The increase in the number of gallons of water supplied in 1875, as compared with 1865, was nearly 37 per cent. The amount supplied for the year 1878 was an average of nearly 53,000,000 gallons per day. These two factors were then adopted as a basis, and the surveys and examinations made for the purpose of securing a minimum supply of 150 million gallons per day, delivered into a reservoir in the city at an elevation not less than 170 feet above city datum. Surveys were made of all the streams of any importance within thirty miles of the city. The Delaware River was also examined as far up as the Water Gap.

The Perkiomen was found to possess all the requirements of quantity and elevation, and, so far as present and prospective comparative purity of the water, it was equaled by none of the other sources examined. This stream was, therefore, recommended.

A most desirable location was found for an impounding reservoir, not at as great an elevation as desired; but the location admits of the construction of a dam of almost any height. As it is neither necessary nor desirable that the inlet of the aqueduct should be placed at or near the bottom, it was only intended to draw the water for the city from the upper part of the dam, leaving the lower part for the accumulation of suspended matter brought into the reservoir with the water.

Surveys were made for the purpose of ascertaining if the minimum head, 170 feet, could be secured, and it was found that by raising the water by impounding 65 feet, the surface would be 204 feet above city datum, and cover 1500 acres. This would give ample head to overcome friction of the aqueduct, and allow the dam to be drawn down from 12 to 15 feet.

The bottom of the Croton aqueduct at the gate chamber is but 11.4 feet below the surface of the dam, and the Loch Katrine aqueduct

draws the lake down seven feet below its overflow. The height of the proposed dam need not be restricted to 65 feet; it can be made 100 feet deep, or deeper, if necessary.

It is to be regretted that no surveys have been made which would enable the actual location of a line of aqueduct, but from some little preliminary work and an examination of the country between the Perkiomen and the city, lines of aqueduct at the proposed elevation are practicable by several routes.

Being confident that the Perkiomen would be the source, and gravitation the mode of supply, at some time in the future, a reservoir was located in the 24th ward, George's Hill, north of the present reservoir, and was placed at an elevation of 180 feet, to form a part of this system of supply. This was to have been constructed by shutting up the end of the ravine along Belmont avenue, thus forming an artificial lake which would have stored 225 million gallons and cost but one-half as much as the reservoir built in its stead, which stores but 30 million gallons. It is true, the surface of the water in the present basin is 32 feet higher than the one proposed and commenced would have been. This greater elevation commands but a very small additional area, and is not of sufficient altitude for the high lying portions of this district. The change in location has not only given the city a much smaller reservoir, at a largely increased cost, but entails an annual expense for pumping the water to an unnecessary height, which in 1878 amounted to \$7,121.46.

This, then, is what was supposed or intended to be done by the Perkiomen project:

OBJECTIONS ANSWERED.

Mr. Smith's objections to the original site selected for the construction of the impounding reservoir are, first, as follows: "It will be observed the conduit from the lake was not designed to deliver water into the receiving basin in the city at a greater elevation than 133 feet above city datum." This conclusion is arrived at from statements in the report of the Commission of Engineers; but it has been demonstrated by actual surveys that a dam of but 65 feet in depth would deliver water by gravitation into a reservoir in the city 170 feet above city datum, and allow the water in the proposed lake to be drawn down 12 feet. These facts have never been controverted, and the Commission of Engineers used the same figures; therefore it is evident that they proposed to lose 47 feet in the declivity or fall of

the conduit to the city; an unnecessary head, as Mr. Smith's calculations demonstrate. He estimates a loss of 25.94 feet in the entire length of his proposed conduit, or 0.94 feet per mile. The fall in the Croton aqueduct, New York, is from 0.504 to 1.106 feet per mile. The fall in Cochituate aqueduct, Boston, is but 0.45 feet per mile, including the pipe conduit; in Loch Katrine aqueduct it is 0.833 feet per mile, and in the Washington aqueduct 0.792 feet to the mile. I proposed to use a fall of 20 feet, or 0.727 feet per mile, in bringing in the water of the Perkionmen.

From the above it is evident that the first location has sufficient elevation, and it was designed to supply all the reservoirs in the city with the exception of the Roxborough and Mt. Airy, which have an altitude of 365 feet. This location was also selected by the Commission of Engineers, who proposed a dam ten feet deeper than the surveys for the minimum proved to be necessary.

An inspection of the contour map prepared by the Water Department shows that a reservoir with the water surface 180 feet above city datum will practically supply the entire city, so that the proposed additional head of 60 feet will be of little actual value, as it would only supply a narrow strip, lying between an elevation of 130 and 190 feet, not three square miles in area. This additional pressure would make it necessary to empty 95 per cent. of the water into and supply it from reservoirs of less elevation, as the head on the low lying districts would be unmanageable and destructive to the old pipe systems.

The reservoirs known as the Schuylkill, Delaware, and Corinthian avenue, when considered as a part of the water supply of a great city, are of little importance on account of their limited storage capacity. The ground they occupy, and the increased value their removal would give to the property in their immediate vicinity, would go far towards paying for a reservoir of ample capacity at a proper elevation. These should therefore not stand in the way of an arrangement which would place practically the entire city under one system of supply. If it has been demonstrated that the location for the dam on the main stream of the Perkionmen above Schwoncksville has a sufficient head, then the objections on that account may be considered as answered.

The second objection is "the great length of the mound dam." When you are informed that a dam 1100 feet long on the top will raise the water 65 feet and cover 1500 acres, and that the storage capa-

city of the first 12 feet below the overflow would be 5,000,000,000 gallons, and that the foundations and abutments of the dam will be of solid rock, you will see that it will be difficult to find a more desirable location. That suggested by Mr. Smith was examined for a supplementary or feeding reservoir when the demands of the city would make one necessary.

The third objection "is the value of the property submerged and expense of removing the railroad." When my surveys and recommendations were made no railroad existed in the valley. The surveys for a railroad were not made until after mine were completed. This is therefore not a question of engineering, but is simply one of comparative cost, and can only be settled when the value of the property overflowed, and the cost of the several dams which are proposed to take the place of the large one, and the increased length of the aqueduct, at least $4\frac{1}{2}$ miles, have been ascertained; then it will probably be demonstrated that the original location would be the less costly, and it certainly is the most desirable. To carry an aqueduct at the proposed greater elevation would add much to its cost of construction and also to its length.

POINTS SETTLED.

The following important facts in regard to the Perkiomen plan may be claimed as demonstrated:

1st. The comparative purity and desirableness of the water. All who have examined it agree that in this most essential requisite it is now and likely to remain entirely satisfactory.

2d. That there is an abundant supply of water. Mr. McAlpine, one of the Commission of Engineers, estimated the daily average flow of the stream at 331,000,000 gallons. Mr. Smith, by adding the East branch, Indian Run and Towamencin Creek, estimates the daily average flow 272,265,752 gallons. His estimate leaves out six miles of the main valley.

Calculations based upon data in the "Report of the Park Commission" gives the daily average flow, at the point of the original location of the dam, 250,000,000 gallons.

My estimate was 240,000,000 gallons per day, without taking into account the East branch, Skippack, Towamencin, the Wissahickon or or any other stream the waters of which could be brought into the conduit on its way to the city.

There can, therefore, be no question but that from 150,000,000 to

175,000,000 gallons can be secured for a supply for the city after making all deductions for evaporation, soakage and waste of storm water; an abundant supply of water for a city of more than double the inhabitants Philadelphia now contains, with enough to supply the towns near which the line of aqueduct would pass, and sufficient for the city of Camden, should it desire to be supplied from this source.

3d. There is sufficient elevation to furnish all the city with water by gravitation from the first location, with but trifling exceptions, not amounting to over three per cent. of all the water required.

The strange indifference of the public in reference to this project, and the unwillingness of the municipal authorities to investigate it, make its advocacy embarrassing and almost hazardous to the reputation of an engineer; but after the unanimous endorsement of the Commission of Engineers and the pains taken by one of them, the most experienced in water works construction—William J. McAlpine—to present it somewhat in detail, with general plans and estimates, and the endorsement, after a thorough examination of the subject, by Mr. James F. Smith, C. E., may we not hope that the project will at least be thoroughly investigated by our municipal authorities?

Efforts to interest leading men in the city government have been met with the reply of "What is the use of talking about it? the city cannot increase its indebtedness or undertake any enterprise of such magnitude." Yet since the Perkioinen project has been before Councils over five millions of dollars has been expended upon the enlargement of the water works. Some of this money has been worse than thrown away, and to-day the supply of water to the city is not as full, when the number of inhabitants is taken into account. Very few of the extensions are of such a character as to be of a permanent nature, and are only sufficient to meet the pressing necessities of the present demands. Such appears to be the policy for the future, and it will be necessary to make large appropriations almost every year for extensions.

A supply flowing into the city by gravitation would also save \$150,000 per annum in cost of operating the works. It is therefore evident that the city can save nothing by pursuing its present policy in relation to its water supply. Works of the proposed character and capacity when completed will require no further expenditures for many years to come, and allow the burdened tax-payer rest, so far as

the demand for water works extension is concerned, for a generation or more.

The cross sections of the different aqueducts are :

BOSTON, COCHITUATE.—Brick conduit, oviform, 6 feet 4 inches by 5 feet. 14.627 miles long. Total fall, 3.74 feet.

MYSTIC POND.—Brick conduit, oviform, 5 feet by 5 feet 8 inches. 3000 feet long. Fall, 0.5 foot per mile.

SUDBURY RIVER.—7 feet 8 inches by 9 feet ; 16 miles long ; capacity, 70 million gallons per day ; fall, 1.055 feet per mile.

NEW YORK, CROTON.—7 feet 5 inches by 8 feet 5½ inches ; length, 38 miles ; fall, 0.504 to 1.106 feet per mile.

BALTIMORE. *Old Aqueduct*.—Same as Cochituate ; fall, 1 foot per mile ; flow, 30,000,000 gallons per day ; 4¾ miles long. *New Aqueduct*.—12 feet diameter, 7 miles long ; fall, one foot per mile ; capacity, 170 million gallons per day.

WASHINGTON.—9 feet diameter, 11½ miles long, fall, 0.792 feet per mile ; capacity, 67 million gallons per day.

Using Robert K. Martin's formula, incorrectly printed in the JOURNAL of October, page 244,

$$V = \sqrt{\frac{180 \times \text{head in feet} \times \text{diameter in inches}}{\text{Length in feet.}}}$$

An aqueduct from the Perkiomen to the city, 26 miles long, 14 feet diameter, with a fall of 20 feet, will discharge 200 million gallons per day.

Limits of the Animal and Vegetable Kingdoms.—Prof. Stein, in his beautiful work on the flagellate Infusoria, distinguishes the lowest animals from vegetables by the simultaneous presence of vibratile cilia; contractile cavities and a nucleus. Protozoans have all three of these organs, but he thinks this cannot be said of any vegetable. E. Maupas shows that the zoospores of two Algæ, the *Microspora floccosa* and an unclassified *Oedogonium*, have well-marked nuclei, together with the cilia and contractile cavity, and concludes that neither physiology nor morphology furnishes any criterion for distinguishing animals from vegetables. Claude Bernard has established the biological unity of all living organisms, and Protozoans and Protophytes can only be classified by means of their tendencies and affinities.—*Comptes Rendus*. C.

ON RADIANT MATTER.

A Lecture delivered to the British Association for the Advancement of Science
at Sheffield, Friday, August 22d, 1879.

By WILLIAM CROOKES, F. R. S.

To throw light on the title of this lecture I must go back more than sixty years—to 1816. Faraday, then a mere student and ardent experimentalist, was 24 years old, and at this early period of his career he delivered a series of lectures on the General Properties of Matter, and one of them bore the remarkable title, *On Radiant Matter*. The great philosopher's notes of this lecture are to be found in Dr. Benec Jones's "Life and Letters of Faraday," and I will here quote a passage in which he first employs the expression *Radiant Matter*:

"If we conceive a change as far beyond vaporization as that is above fluidity, and then take into account also the proportional increased extent of alteration as the changes rise, we shall perhaps, if we can form any conception at all, not fall far short of Radiant Matter; and as in the last conversion many qualities were lost, so here also many more would disappear."

Faraday was evidently engrossed with this far-reaching speculation, for three years later—in 1819—we find him bringing fresh evidence and argument to strengthen his startling hypothesis. His notes are now more extended, and they show that in the intervening three years he had thought much and deeply on this higher form of matter. He first points out that matter may be classed into four states—solid, liquid, gaseous and radiant—these modifications depending upon differences in their several essential properties. He admits that the existence of Radiant Matter is as yet unproved, and then proceeds, in a series of ingenious analogical arguments, to show the probability of its existence.

* "I may now notice a curious progression in physical properties accompanying changes of form, and which is perhaps sufficient to induce, in the inventive and sagacious philosopher, a considerable degree of belief in the association of the radiant form with the others in the set of changes I have mentioned.

"As we ascend from the solid to the fluid and gaseous states, physical properties diminish in number and variety, each state losing some of those which belonged to the preceding state. When solids are converted into fluids, all the varieties of hardness and softness are necessarily lost. Crystalline and other shapes are destroyed.

If, in the beginning of this century, we had asked, What is a gas? the answer then would have been that it is matter, expanded and rarefied to such an extent as to be impalpable, save when set in violent motion; invisible, incapable of assuming or of being reduced into any definite form like solids, or of forming drops like liquids; always ready to expand where no resistance is offered, and to contract on being subjected to pressure. Sixty years ago such were the chief attributes assigned to gases. Modern research, however, has greatly enlarged and modified our views on the constitution of these elastic fluids. Gases are now considered to be composed of an almost infinite number of small particles or molecules, which are constantly moving in every direction with velocities of all conceivable magnitudes. As these molecules are exceedingly numerous, it follows that no molecule can move far in any direction without coming in contact with some other molecule. But if we exhaust the air or gas contained in a closed vessel, the number of molecules become diminished, and the distance through which any one of them can move without coming in contact with another is increased, the length of the mean free path being inversely proportional to the number of molecules present. The further this process is carried the longer becomes the average distance a molecule can travel before entering into collision; or, in other words, the longer its mean free path, the more the physical properties of the gas or air are modified. Thus, at a certain point, the phenomena of the radiometer become possible, and on pushing the rarefaction still further,

Opacity and color frequently give way to a colorless transparency, and a general mobility of particles is conferred.

“Passing onward to the gaseous, still more of the evident characters of bodies are annihilated. The immense differences in their weight almost disappear; the remains of difference in color that were left, are lost. Transparency becomes universal, and they are all elastic. They now form but one set of substances, and the varieties of density, hardness, opacity, color, elasticity and form, which render the number of solids and fluids almost infinite, are now supplied by a few slight variations in weight, and some unimportant shades of color.

“To those, therefore, who admit the radiant form of matter, no difficulty exists in the simplicity of the properties it possesses, but rather an argument in their favor. These persons show you a gradual resignation of properties in the matter we can appreciate as the matter ascends in the scale of forms, and they would be surprised if that effect were to cease at the gaseous state. They point out the greater exertions which Nature makes at each step of the change, and think that, consistently, it ought to be greatest in the passage from the gaseous to the radiant form.”—*Life and Letters of Faraday*, vol 1, p. 308.

i. e. decreasing the number of molecules in a given space and lengthening their mean free path, the experimental results are obtainable to which I am now about to call your attention. So distinct are these phenomena from anything which occurs in air or gas at the ordinary tension, that we are led to assume that we are here brought face to face with Matter in a Fourth state or condition, a condition as far removed from the state of gas as a gas is from a liquid.

MEAN FREE PATH. RADIANT MATTER.

I have long believed that a well-known appearance observed in vacuum tubes is closely related to the phenomena of the mean free path of the molecules. When the negative pole is examined while the discharge from an induction-coil is passing through an exhausted tube, a dark space is seen to surround it. This dark space is found to increase

Fig. 1.



and diminish as the vacuum is varied, in the same way that the mean free path of the molecules lengthens and contracts. As the one is perceived by the mind's eye to get greater, so the other is seen by the bodily eye to increase in size; and if the vacuum is insufficient to permit much play of the molecules before they enter into collision, the passage of electricity shows that the "dark space" has shrunk to small dimensions. We naturally infer that the dark space is the mean free path of the molecules of the residual gas, an inference confirmed by experiment.

I will endeavor to render this "dark space" visible to all present. Here is a tube (Fig. 1), having a pole in the centre in the form of a metal disk, and other poles at each end. The centre pole is made

negative, and the two end poles connected together are made the positive terminal. The dark space will be in the centre. When the exhaustion is not very great the dark space extends only a little on each side of the negative pole in the centre. When the exhaustion is good, as in the tube before you, and I turn on the coil, the dark space is seen to extend for about an inch on each side of the pole.

Here, then, we see the induction spark actually illuminating the lines of molecular pressure caused by the excitement of the negative pole. The thickness of this dark space is the measure of the mean free path between successive collisions of the molecules of the residual gas. The extra velocity with which the negatively electrified molecules rebound from the excited pole keeps back the more slowly moving molecules which are advancing toward that pole. A conflict occurs at the boundary of the dark space, where the luminous margin bears witness to the energy of the discharge.

Therefore the residual gas—or, as I prefer to call it, the gaseous residue—within the dark space is an entirely different state to that of the residual gas in vessels at a lower degree of exhaustion. To quote the words of our last year's President, in his Address at Dublin:—

“In the exhausted column we have a vehicle for electricity not constant like an ordinary conductor, but itself modified by the passage of the discharge, and perhaps subject to laws differing materially from those which it obeys at atmospheric pressure.”

In the vessels with the lower degree of exhaustion, the length of the mean free path of the molecules is exceedingly small as compared with the dimensions of the bulb, and the properties belonging to the ordinary gaseous state of matter, depending upon constant collisions, can be observed. But in the phenomena now about to be examined, so high is the exhaustion carried that the dark space around the negative pole has widened out till it entirely fills the tube. By great rarefaction the mean free path has become so long that the hits in a given time in comparison to the misses may be disregarded, and the average molecule is now allowed to obey its own motions or laws without interference. The mean free path, in fact, is comparable to the dimensions of the vessel, and we have no longer to deal with a *continuous* portion of matter, as would be the case were the tubes less highly exhausted, but we must here contemplate the molecules *individually*. In these highly exhausted vessels the molecules of the gaseous residue are able to dart across the tube with comparatively few collisions, and radiating from

the pole with enormous velocity, they assume properties so novel and so characteristic as to entirely justify the application of the term borrowed from Faraday, that of *Radiant Matter*.

RADIANT MATTER EXERTS POWERFUL PHOSPHORESCENT ACTION WHERE IT STRIKES.

I have mentioned that the Radiant Matter within the dark space excites luminosity where its velocity is arrested by residual gas outside the dark space. But if no residual gas is left, the molecules will have their velocity arrested by the sides of the glass; and here we come to the first and one of the most noteworthy properties of Radiant Matter discharged from the negative pole—its power of exciting phosphorescence when it strikes against solid matter. The number of bodies

Fig. 2



which respond luminously to this molecular bombardment is very great, and the resulting colors are of every variety. Glass, for instance, is highly phosphorescent when exposed to a stream of Radiant Matter. Here (Fig. 2) are three bulbs composed of different glass; one is uranium glass (*a*), which phosphoresces of a dark green color; another is English glass (*b*), which phosphoresces of a blue color; and the third (*c*) is soft German glass—of which most of the apparatus before you is made—which phosphoresces of a bright apple green.

My earlier experiments were almost entirely carried on by the aid of the phosphorescence that glass takes up when it is under the influence of the radiant discharge; but many other substances possess this phosphorescent power in a still higher degree than glass. For instance, here is some of the luminous sulphide of calcium prepared according to M. Ed. Becquerel's description. When the sulphide is exposed to

light—even candlelight—it phosphoresces for hours with a bluish white color. It is, however, much more strongly phosphorescent to the molecular discharge in a good vacuum, as you will see when I pass the discharge through this tube.

Other substances besides English, German, and uranium glass, and Becquerel's luminous sulphides, are also phosphorescent. The rare mineral phenacite (aluminate of glucinum) phosphoresces blue; the mineral spodumene (a silicate of aluminium and lithium) phosphoresces a rich golden yellow; the emerald gives out a crimson light. But without exception, the diamond is the most sensitive substance I have yet met for ready and brilliant phosphorescence. Here is a very

Fig. 3.



curious fluorescent diamond, green by daylight, colorless by candlelight. It is mounted in the centre of an exhausted bulb (Fig. 3), and the molecular discharge will be directed on it from below upward. On darkening the room you see the diamond shines with as much light as a candle, phosphorescing of a bright green.

Next to the diamond the ruby is one of the most remarkable stones for phosphorescing. In this tube (Fig. 4) is a fine collection of ruby pebbles. As soon as the induction spark is turned on you will see these rubies shining with a brilliant rich red tone, as if they were glowing hot. It

scarcely matters what color the ruby is, to begin with. In this tube of natural rubies there are stones of all colors—the deep red and also the pale pink ruby. There are some so pale as to be almost colorless, and some of the highly-prized tint of pigeon's blood; but under the impact of Radiant Matter they all phosphoresce with about the same color.

Fig. 4.



Now the ruby is nothing but crystallized alumina with a little coloring matter. In a paper by Ed. Becquerel,* published twenty years ago, he describes the appearance of alumina as glowing with a rich red color in the phosphoscope. Here is some precipitated alumina prepared in the most careful manner. It has been heated to whiteness, and you see it also glows under the molecular discharge with the same rich red color.

The spectrum of the red light emitted by these varieties of alumina is the same as described by Becquerel twenty years ago. There is one intense red line, a little below the fixed line B in the spectrum, having a wave-length of about 6895. There is a continuous spectrum beginning at about B, and a few fainter lines beyond it, but they are so faint in comparison with this red line that they may be neglected. This line is easily seen by examining with a small pocket spectroscope the light reflected from a good ruby.

There is one particular degree of exhaustion more favorable than any other for the development of the properties of Radiant Matter which are now under examination. Roughly speaking it may be put at the millionth of an atmosphere.† At this degree of exhaustion the

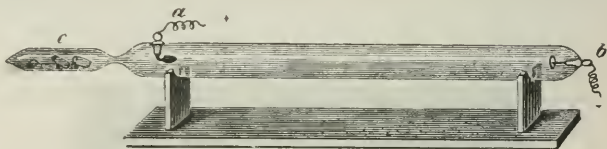
* *Annales de Chimie et de Physique*, 3^e série, vol. LVII, p. 50, 1870.

†	1.0 millionth of an atmosphere	0.00075 millim.
	1315.789 millionths of an atmosphere	1.0 millim.
	1,000,000 "	760.0 millims.
	"	1 atmosphere.

phosphorescence is very strong, and after that it begins to diminish until the spark refuses to pass.*

I have here a tube (Fig. 5) which will serve to illustrate the depen-

Fig. 5.



dence of the phosphorescence of the glass on the degree of exhaustion. The two poles are at *a* and *b*, and at the end (*c*) is a small supplementary

*Nearly 100 years ago Mr. Wm. Morgan communicated to the Royal Society a Paper entitled "Electrical Experiments made to ascertain the Non-conducting Power of a Perfect Vacuum, etc." The following extracts from this Paper, which was published in the *Phil. Trans.* for 1785 (vol. lxxv, p. 272), will be read with interest:

"A mercurial gage about fifteen inches long, carefully and accurately boiled till every particle of air was expelled from the inside, was coated with tin-foil five inches down from its sealed end, and being inverted into mercury through a perforation in the brass cap which covered the mouth of the cistern; the whole was cemented together, and the air was exhausted from the inside of the cistern through a valve in the brass cap, which producing a perfect vacuum in the gage formed an instrument peculiarly well adapted for experiments of this kind. Things being thus adjusted (a small wire having been previously fixed on the inside of the cistern to form a communication between the brass cap and the mercury, into which the gage was inverted) the coated end was applied to the conductor of an electrical machine, and notwithstanding every effort, neither the smallest ray of light, nor the slightest charge, could ever be procured in this exhausted gage."

"If the mercury in the gage be imperfectly boiled, the experiment will not succeed; but the color of the electric light, which in air rarefied by an exhauster is always violet or purple, appears in this case of a beautiful green, and, what is very curious, the degree of the air's rarefaction may be nearly determined by this means; for I have known instances, during the course of these experiments, where a small particle of air having found its way into the tube, the electric light became visible, and as usual of a green color; but the charge being often repeated, the gage has at length cracked at its sealed end, and in consequence the external air, by being admitted into the inside, has gradually produced a change in the electric light from green to blue, from blue to indigo, and so on to violet and purple, till the medium has at length become so dense as no longer to be a conductor of electricity. I think there can be little doubt, from the above experiments, of the non-conducting power of a perfect vacuum."

"This seems to prove that there is a limit even in the rarefaction of air, which sets bounds to its conducting power; or, in other words, that the particles of air may be so far separated from each other as no longer to be able to transmit the electric fluid; that if they were brought within a certain distance of each other, their conducting power begins, and continually increases till their approach also arrives at its limit."

tube connected with the other by a narrow aperture, and containing solid caustic potash. The tube has been exhausted to a very high point, and the potash treated so as to drive off moisture and injure the vacuum. Exhaustion has then been re-commenced, and the alternate heating and exhaustion repeated until the tube has been brought to the state in which it now appears before you. When the induction spark is first turned on nothing is visible—the vacuum is so high that the tube is non-conducting. I now warm the potash slightly and liberate a trace of aqueous vapor. Instantly conduction commences, and the green phosphorescence flashes out along the length of the tube. I continue the heat, so as to drive off more gas from the potash. The green gets fainter, and now a wave of cloudy luminosity sweeps over the tube, and stratifications appear, which rapidly get narrower, until the spark passes along the tube in the form of a narrow purple line. I take the lamp away, and allow the potash to cool; as it cools, the aqueous vapor, which the heat had driven off, is re-absorbed. The purple line broadens out, and breaks up into fine stratifications; these get wider, and travel toward the potash tube. Now a wave of green light appears on the glass at the other end, sweeping on and driving the last pale stratification into the potash; and now the tube glows over its whole length with the green phosphorescence. I might keep it before you, and show the green growing fainter and the vacuum becoming non-conducting; but I should detain you too long, as time is required for the absorption of the last traces of vapor by the potash, and I must pass on to the next subject.

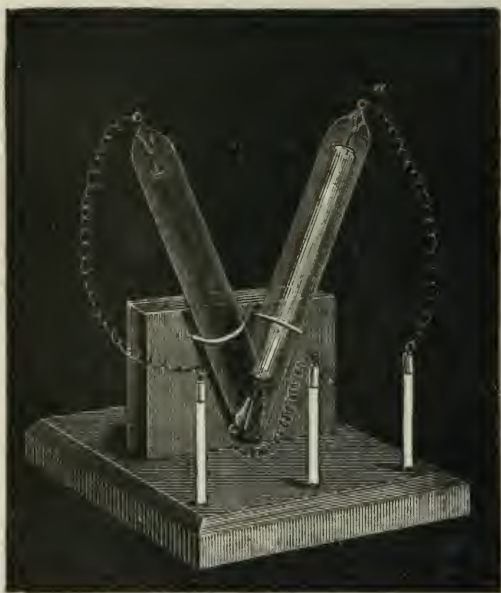
RADIANT MATTER PROCEEDS IN STRAIGHT LINES.

The Radiant Matter, whose impact on the glass causes an evolution of light, absolutely refuses to turn a corner. Here is a V shaped tube (Fig. 6), a pole being at each extremity. The pole at the right side being negative, you see that the whole of the right arm is flooded with green light, but at the bottom it stops sharply and will not turn the corner to get into the left side. When I reverse the current and make the left pole negative, the green changes to the left side, always following the negative pole and leaving the positive side with scarcely any luminosity.

In the ordinary phenomena exhibited by vacuum tubes—phenomena with which we are all familiar—it is customary, in order to bring out the striking contrasts of color, to bend the tubes into very elaborate designs. The luminosity caused by the phosphorescence of the residual

gas follows all the convolutions into which skillful glass-blowers can manage to twist the glass. The negative pole being at one end and the positive pole at the other, the luminous phenomena seem to depend more on the positive than on the negative at the ordinary exhaustion hitherto used to get the best phenomena of vacuum tubes. But at a very high exhaustion the phenomena noticed in ordinary vacuum tubes when the induction spark passes through them—an appearance of cloudy luminosity and of stratifications—disappear entirely. No cloud

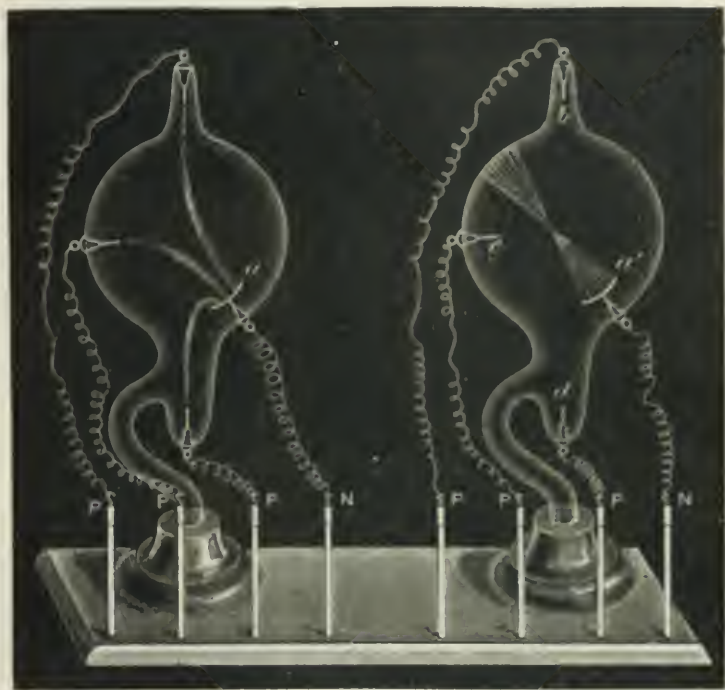
Fig. 6.



or fog whatever is seen in the body of the tube, and with such a vacuum as I am working with in these experiments, the only light observed is that from the phosphorescent surface of the glass. I have here two bulbs (Fig. 7), alike in shape and position of poles, the only difference being that one is at an exhaustion equal to a few millimetres of mercury—such a moderate exhaustion as will give the ordinary luminous phenomena—while the other is exhausted to about the millionth of an atmosphere. I will first connect the moderately exhausted bulb (A) with the induction-coil, and retaining the pole at one side (*a*) always negative, I will put the positive wire successively to the other poles

with which the bulb is furnished. You see that as I change the position of the positive pole, the tinge of violet light joining the two poles changes, the electric current always choosing the shortest path between the two poles, and moving about the bulb as I alter the position of the wires.

Fig. 7.



This, then, is the kind of phenomenon we get in ordinary exhaustions. I will now try the same experiment with a bulb (B) that is very highly exhausted, and as before, will make the side pole (a') the negative, the top pole (b) being positive. Notice how widely different is the appearance from that shown by the last bulb. The negative pole is in the form of a shallow cup. The molecular rays from the cup cross in the centre of the bulb, and thence diverging fall on the opposite side and produce a circular patch of green phosphorescent light. As I turn the bulb round you will all be able to see the green patch on the glass. Now observe, I remove the positive wire from the top, and connect it with the side pole (c). The green patch from the divergent negative focus is there still. I now make the lowest pole (d)

positive, and the green patch remains where it was at first, unchanged in position or intensity.

We have here another property of Radiant Matter. In the low vacuum the position of the positive pole is of every importance, while in a high vacuum the position of the positive pole scarcely matters at all; the phenomena seem to depend entirely on the negative pole. If the negative pole points in the direction of the positive, all very well, but if the negative pole is entirely in the opposite direction it is of little consequence; the Radiant Matter darts all the same in a straight line from the negative.

Fig. 8.



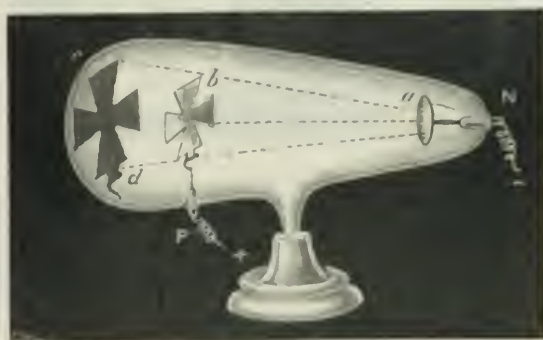
If, instead of a flat disk, a hemi-cylinder is used for the negative pole, the Matter still radiates normal to its surface. The tube before you (Fig. 8) illustrates this property. It contains, as a negative pole, a hemi-cylinder (*a*) of polished aluminium. This is connected with a fine copper wire, *b*, ending at the platinum terminal, *c*. At the upper end of the tube is another terminal, *d*. The induction-coil is connected so that the hemi-cylinder is negative and the upper pole positive, and when exhausted to a sufficient extent the projection of the molecular rays to a focus is very beautifully shown. The rays of Matter being driven from the hemi-cylinder in a direction normal to its surface, come to a focus and then diverge, tracing their path in brilliant green phosphorescence on the surface of the glass.

Instead of receiving the molecular rays on the glass, I will show you another tube in which the focus falls on a phosphorescent screen. See how brilliantly the lines of discharge shine out, and how intensely the focal point is illuminated, lighting up the table.

RADIANT MATTER WHEN INTERCEPTED BY SOLID MATTER CASTS A SHADOW.

Radiant Matter comes from the pole in straight lines, and does not merely permeate all the parts of the tube and fill it with light, as would be the case were the exhaustion less good. Where there is nothing in the way the rays strike the screen and produce phosphorescence, and where solid matter intervenes they are obstructed by it, and a shadow is thrown on the screen. In this pear-shaped bulb (Fig. 9) the negative pole (*a*) is at the pointed end. In the middle is a cross (*b*) cut

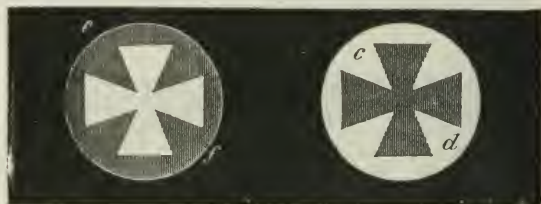
Fig. 9.



out of sheet aluminium, so that the rays from the negative pole projected along the tube will be partly intercepted by the aluminium cross, and will project an image of it on the hemispherical end of the tube, which is phosphorescent. I turn on the coil, and you will all see the black shadow of the cross on the luminous end of the bulb (*c, d*). Now, the Radiant Matter from the negative pole has been passing by the side of the aluminium cross to produce the shadow; the glass has been hammered and bombarded till it is appreciably warm, and at the same time another effect has been produced on the glass—its sensibility has been deadened. The glass has got tired, if I may use the expression, by the enforced phosphorescence. A change has been produced by this molecular bombardment which will prevent the glass from responding easily to additional excitement; but the part that the shadow has fallen on is not tired—it has not been phosphorescing at all and is perfectly fresh; therefore if I throw down this cross—I can easily do so by giving the apparatus a slight jerk, for it has been most ingeniously constructed with a hinge by Mr. Gimmingham—and so allow the

rays from the negative pole to fall uninterruptedly on to the end of the bulb, you will suddenly see the black cross (*c, d*, Fig. 10) change to a luminous one (*e, f*), because the background is now only capable of faintly phosphorescing, while the part which had the black shadow on it retains its full phosphorescent power. The stenciled image of the luminous cross unfortunately soon dies out. After a period of rest the glass partly recovers its power of phosphorescing, but it is never so good as it was at first.

Fig. 10.

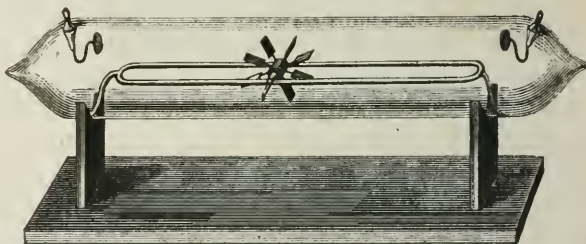


Here, therefore, is another important property of Radiant Matter. It is projected with great velocity from the negative pole, and not only strikes the glass in such a way as to cause it to vibrate and become temporarily luminous while the discharge is going on, but the molecules hammer away with sufficient energy to produce a permanent impression upon the glass.

RADIANT MATTER EXERTS STRONG MECHANICAL ACTION WHERE IT STRIKES.

We have seen, from the sharpness of the molecular shadows, that Radiant Matter is arrested by solid matter placed in its path. If this

Fig. 11.



solid body is easily moved the impact of the molecules will reveal itself in strong mechanical action. Mr. Gimmingham has constructed for me an ingenious piece of apparatus which when placed in the elec-

tric lantern will render this mechanical action visible to all present. It consists of a highly exhausted glass tube (Fig. 11), having a little glass railway running along it from one end to the other. The axle of a small wheel revolves on the rails, the spokes of the wheel carrying wide mica paddles. At each end of the tube, and rather above the centre, is an aluminium pole, so that whichever pole is made negative the stream of Radiant Matter darts from it along the tube, and striking the upper vanes of the little paddle-wheel causes it to turn round and travel along the railway. By reversing the poles I can arrest the wheel and send it the reverse way, and if I gently incline the tube the force of impact is observed to be sufficient even to drive the wheel up hill.

Fig. 12.

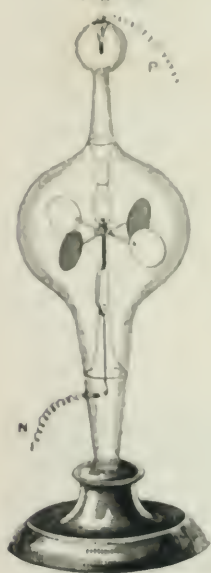
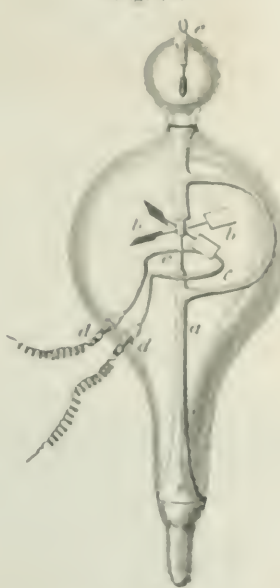


Fig. 13.



This experiment, therefore, shows that the molecular stream from the negative pole is able to move any light object in front of it.

The molecules being driven violently from the pole there should be a recoil of the pole from the molecules, and by arranging an apparatus so as to have the negative pole movable and the body receiving the impact of the Radiant Matter fixed, this recoil can be rendered sensible. In appearance the apparatus (Fig. 12) is not unlike an ordinary radiometer with aluminium disks for vanes, each disk coated on one side with

a film of mica. The fly is supported by a hard steel instead of glass cup, and the needle point on which it works is connected by means of a wire with a platinum terminal sealed into the glass. At the top of the radiometer bulb a second terminal is sealed in. The radiometer, therefore, can be connected with an induction-coil, the movable fly being made the negative pole.

For these mechanical effects the exhaustion need not be so high as when phosphorescence is produced. The best pressure for this electrical radiometer is a little beyond that at which the dark space round the negative pole extends to the sides of the glass bulb. When the pressure is only a few millims. of mercury, on passing the induction current a halo of velvety violet light forms on the metallic side of the vanes, the mica side remaining dark. As the pressure diminishes, a dark space is seen to separate the violet halo from the metal. At a pressure of half a millimetre this dark space extends to the glass, and rotation commences. On continuing the exhaustion the dark space further widens out and appears to flatten itself against the glass, when the rotation becomes very rapid.

Here is another piece of apparatus (Fig. 13) which illustrates the mechanical force of the Radiant Matter from the negative pole. A stem (*a*) carries a needle-point in which revolves a light mica fly (*b b*). The fly consists of four square vanes of thin clear mica, supported on light aluminium arms, and in the centre is a small glass cap which rests on the needle-point. The vanes are inclined at an angle of 45° to the horizontal plane. Below the fly is a ring of fine platinum wire (*c c*), the ends of which pass through the glass at *d d*. An aluminium terminal (*e*) is sealed in at the top of the tube, and the whole is exhausted to a very high point.

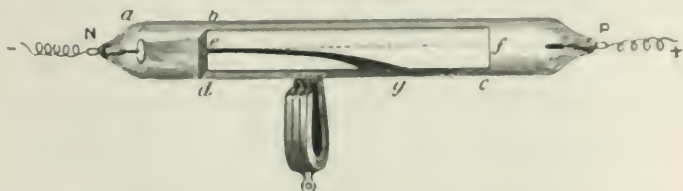
By means of the electric lantern I project an image of the vanes on the screen. Wires from the induction-coil are attached, so that the platinum ring is made the negative pole, the aluminium wire (*e*) being positive. Instantly, owing to the projection of Radiant Matter from the platinum ring, the vanes rotate with extreme velocity. Thus far the apparatus has shown nothing more than the previous experiments have prepared us to expect; but observe what now happens. I disconnect the induction-coil altogether, and connect the two ends of the platinum wire with a small galvanic battery; this makes the ring *c c* red hot, and under this influence you see that the vanes spin as fast as they did when the induction-coil was at work.

Here, then, is another most important fact. Radiant Matter in these high vacua is not only excited by the negative pole of an induction-coil, but a hot wire will set it in motion with force sufficient to drive round the sloping vanes.

RADIANT MATTER IS DEFLECTED BY A MAGNET.

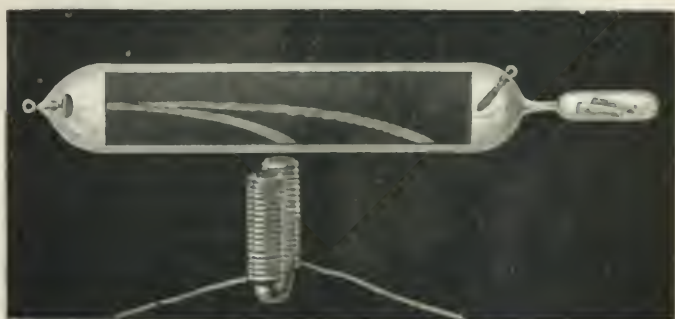
I now pass to another property of Radiant Matter. This long glass-tube (Fig. 14) is very highly exhausted; it has a negative pole at one end and a long phosphorescent screen down the centre of the tube.

Fig. 14.



In front of the negative pole is a plate of mica (*b*, *d*) with a hole (*e*) in it, and the result is, when I turn on the current, a line of phosphorescent light (*e*, *f*) is projected along the whole length of the tube. I now place beneath the tube a powerful horse-shoe magnet; observe how the line of light becomes curved under the magnetic influence waving about like a flexible wand as I move the magnet to and fro.

Fig. 15.

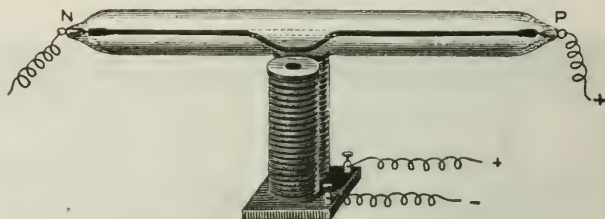


This action of the magnet is very curious, and if carefully followed up will elucidate other properties of Radiant Matter. Here (Fig. 15) is an exactly similar tube, but having at one end a small potash tube, which, if heated, will slightly injure the vacuum. I turn on the

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induction current, and you see the ray Radiant Matter tracing its trajectory in a curved line along the screen, under the influence of the horse-shoe magnet beneath. Observe the shape of the curve. The molecules shot from the negative pole may be likened to a discharge of iron bullets from a mitrailleuse, and the magnet beneath will represent the earth curving the trajectory of the shot by gravitation. Here on this luminous screen you see the curved trajectory of the shot accurately traced. Now suppose the deflecting force to remain constant, the curve traced by the projectile varies with the velocity. If I put more powder in the gun the velocity will be greater and the trajectory flatter, and if I interpose a denser resisting medium between the gun and the target, I diminish the velocity of the shot, and thereby cause it to move in a greater curve and come to the ground sooner. I cannot well increase before you the velocity of my stream of radiant molecules by putting more powder in my battery, but I will try and make them suffer greater resistance in their flight from one end of the tube to the other. I heat the caustic potash with a spirit-lamp and so throw in a trace more gas. Instantly the stream of Radiant Matter responds. Its velocity is impeded, the magnetism has longer time on which to act on the individual molecules, the trajectory gets more and more curved, until, instead of shooting nearly to the end of the tube, my molecular bullets fall to the bottom before they have got more than half way.

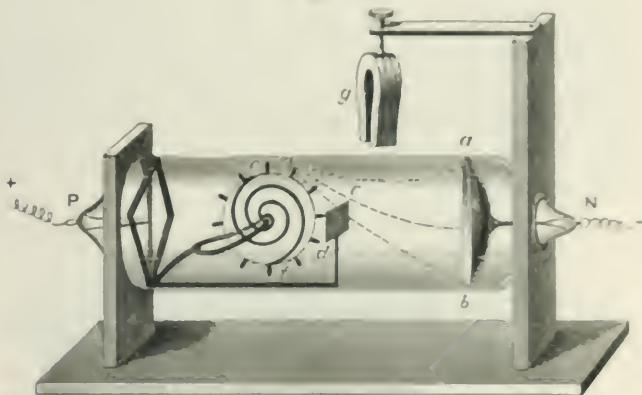
Fig. 16.



It is of great interest to ascertain whether the law governing the magnetic deflection of the trajectory of Radiant Matter is the same as has been found to hold good at a lower vacuum. The experiments I have just shown you were with a very high vacuum. Here is a tube with a low vacuum (Fig. 16). When I turn on the induction spark, it passes as a narrow line of violet light joining the two poles. Underneath I have a powerful electro-magnet. I make contact with the magnet, and the line of light dips in the centre toward the magnet. I reverse the

poles, and the line is driven up to the top of the tube. Notice the difference between the two phenomena. Here the action is temporary. The dip takes place under the magnetic influence; the line of discharge then rises and pursues its path to the positive pole. In the high exhaustion, however, after the stream of Radiant Matter had dipped to the magnet it did not recover itself, but continued its path in the altered direction.

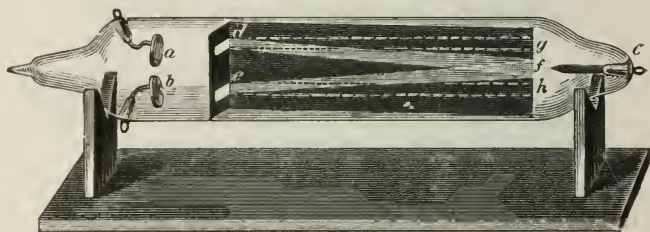
Fig. 17.



By means of this little wheel, skillfully constructed by Mr. Gimmingham, I am able to show the magnetic deflection in the electric lantern. The apparatus is shown in this diagram (Fig. 17). The negative pole (*a, b*) is in the form of a very shallow cup. In front of the cup is a mica screen (*c, d*), wide enough to intercept the Radiant Matter coming from the negative pole. Behind this screen is a mica wheel (*e, f*) with a series of vanes, making a sort of paddle-wheel. So arranged, the molecular ray from the pole *a b* will be cut off from the wheel, and will not produce any movement. I now put a magnet, *g*, over the tube, so as to deflect the stream over or under the obstacle *c d*, and the result will be rapid motion in one or the other direction, according to the way the magnet is turned. I throw the image of the apparatus on the screen. The spiral lines painted on the wheel show which way it turns. I arrange the magnet to draw the molecular stream so as to beat against the upper vanes, and the wheel revolves rapidly as if it were an overshot water-wheel. I turn the magnet so as to drive the Radiant Matter underneath; the wheel slackens speed, stops, and then begins to rotate the other way, like an undershot water-wheel. This can be repeated as often as I reverse the position of the magnet.

I have mentioned that the molecules of the Radiant Matter discharged from the negative pole are negatively electrified. It is probable that their velocity is owing to the mutual repulsion between the similarly electrified pole and the molecules. In less high vacua, such as you saw a few minutes ago (Fig. 16), the discharge passes from one pole to another, carrying an electric current, as if it were a flexible wire. Now it is of great interest to ascertain if the stream of Radiant Matter from the negative pole also carries a current. Here (Fig. 18) is an apparatus which will decide the question at once. The tube contains two negative terminals (*a, b*) close together at one end, and one positive terminal (*c*) at the other. This enables me to send two streams of Radiant Matter side by side along the phosphorescent screen—or by disconnecting one negative pole, only one stream.

Fig. 18.



If the streams of Radiant Matter carry an electric current they will act like two parallel conducting wires and attract one another; but if they are simply built up of negatively electrified molecules they will repel each other.

I will first connect the upper negative pole (*a*) with the coil, and you see the ray shooting along the line *d, f*. I now bring the lower negative pole (*b*) into play, and another line (*e, h*) darts along the screen. But notice the way the first line behaves; it jumps up from its first position, *d f*, to *d g*, showing that it is repelled, and if time permitted I could show you that the lower ray is also deflected from its normal direction; therefore the two parallel streams of Radiant Matter exert mutual repulsion, acting not like current carriers, but merely as similarly electrified bodies.

RADIANT MATTER PRODUCES HEAT WHEN ITS MOTION IS ARRESTED.

During these experiments another property of Radiant Matter has made itself evident, although I have not yet drawn attention to it.

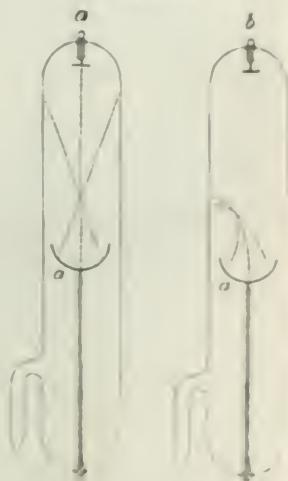
The glass gets very warm where the green phosphorescence is strongest. The molecular focus on the tube, which we saw earlier in the evening (Fig. 8) is intensely hot, and I have prepared an apparatus by which this heat at the focus can be rendered apparent to all present.

I have here a small tube (Fig. 19, *a*) with a cup-shaped negative pole. This cup projects the rays to a focus in the middle of the tube. At the side of the tube is a small electro-magnet, which I can set in action by touching a key, and the focus is then drawn to the side of the glass tube (Fig. 19, *b*). To show the first action of the heat I have coated the tube with wax. I will put the apparatus in front of the electric lantern (Fig. 20, *d*), and throw a magnified image of the tube on the screen. The coil is now at work, and the focus of molecular rays is projected along the tube. I turn the magnetism on, and draw the focus to the side of the glass. The first thing you see is a small circular patch melted in the coating of wax. The glass soon begins to disintegrate, and cracks are shooting starwise from the centre of heat. The glass is softening. Now the atmospheric pressure forces it in, and now it melts. A hole (*c*) is perforated in the middle, the air rushes in, and the experiment is at an end.

I can render this focal heat more evident if I allow it to play on a piece of metal; This bulb (Fig. 21) is furnished with a negative pole in the form of a cup (*a*). The rays will therefore be projected to a focus on a piece of iridio-platinum (*b*) supported in the centre of the bulb.

I first turn on the induction-coil slightly, so as not to bring out its full power. The focus is now playing on the metal, raising it to a white heat. I bring a small magnet near, and you see I can deflect the focus of heat just as I did the luminous focus in the other tube. By shifting the magnet I can drive the focus up and down, or draw it completely away from the metal, and leave it non-luminous. I withdraw the magnet, and let the molecules have full play again; the metal

Fig. 19.



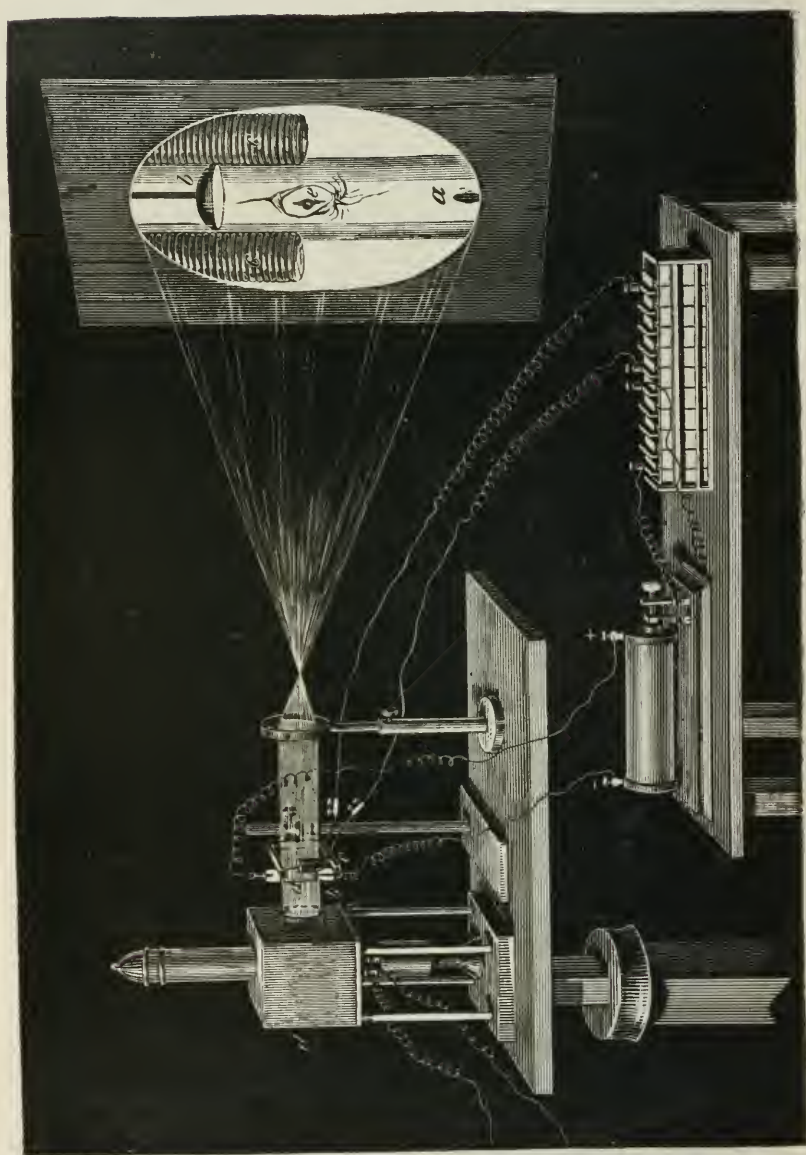


Fig. 20.

is now white hot. I increase the intensity of the spark. The iridio-platinum glows with almost insupportable brilliancy, and at last melts.

THE CHEMISTRY OF RADIANT MATTER.

As might be expected, the chemical distinctions between one kind of Radiant Matter and another at these high exhaustions are difficult to recognize. The physical properties I have been elucidating seem to be common to all matter at this low density. Whether the gas originally under experiment be hydrogen, carbonic acid, or atmospheric air, the phenomena of phosphorescence, shadows, magnetic deflection, etc., are identical, only they commence at different pressures. Other facts, however, show that at this low density the molecules retain their chemical characteristics. Thus by introducing into the tubes appropriate absorbents of residual gas, I can see that chemical attraction goes on long after the attenuation has reached the best stage for showing the phenomena now under illustration, and I am able by this means to carry the exhaustion to much

higher degrees than I can get by mere pumping. Working with aqueous vapor I can use phosphoric anhydride as an absorbent; with carbonic acid, potash; with hydrogen, palladium; and with oxygen, carbon, and then potash. The highest vacuum I have yet succeeded in obtaining has been the 1-20,000,000th of an atmosphere, a degree which may be better understood if I say that it corresponds to about the hundredth of an inch in a barometric column three miles high.

It may be objected that it is hardly consistent to attach primary importance to the presence of *Matter*, when I have taken extraordinary pains to remove as much Matter as possible from these bulbs and these tubes, and have succeeded so far as to leave only about the one millionth of an atmosphere in them. At its ordinary pressure the atmosphere is not very dense, and its recognition as a constituent of the

Fig. 21.



world of Matter is quite a modern notion. It would seem that when divided by a million, so little Matter will necessarily be left that we may justifiably neglect the trifling residue and apply the term *vacuum* to space from which the air has been so nearly removed. To do so, however, would be a great error, attributable to our limited faculties being unable to grasp high numbers. It is generally taken for granted that when a number is divided by a million the quotient must necessarily be small, whereas it may happen that the original number is so large that its division by a million seems to make little impression on it. According to the best authorities, a bulb of the size of the one before you (13·5 centimetres in diameter) contains more than 1,000000, 000000,000000,000000 (a quadrillion) molecules. Now, when exhausted to a millionth of an atmosphere we shall still have a trillion molecules left in the bulb—a number quite sufficient to justify me in speaking of the residue as *Matter*.

To suggest some idea of this vast number I take the exhausted bulb, and perforate it by a spark from the induction coil. The spark produces a hole of microscopical fineness, yet sufficient to allow molecules to penetrate and to destroy the vacuum. The inrush of air impinges against the vanes and sets them rotating after the manner of a wind-mill. Let us suppose the molecules to be of such a size that at every second of time a hundred millions could enter. How long, think you, would it take for this small vessel to get full of air? An hour? A day? A year? A century? Nay, almost an eternity! A time so enormous that imagination itself cannot grasp the reality. Supposing this exhausted glass bulb, indued with indestructibility, had been pierced at the birth of the solar system; supposing it to have been present when the earth was without form and void; supposing it to have borne witness to all the stupendous changes evolved during the full cycles of geologic time, to have seen the first living creature appear, and the last man disappear; supposing it to survive until the fulfillment of the mathematicians' prediction that the sun, the source of energy, four million centuries from its formation will ultimately become a burnt-out cinder;* supposing all this—at the rate of filling I have just described, 100 million molecules a second—this little bulb

*The possible duration of the sun from formation to extinction has been variously estimated, by different authorities, at from 18 million years to 400 million years. For the purpose of this illustration I have taken the highest estimate.

even then would scarcely have admitted its full quadrillion of molecules.*

But what will you say if I tell you that all these molecules, this quadrillion of molecules, will enter through the microscopic hole before you leave this room? The hole being unaltered in size, the number of molecules undiminished, this apparent paradox can only be explained by again supposing the size of the molecules to be diminished almost infinitely—so that instead of entering at the rate of 100 millions every second, they troop in at the rate of something like 300 trillions a second. I have done the sum, but figures when they mount so high cease to have any meaning, and such calculations are as futile as trying to count the drops in the ocean.

In studying this Fourth state of Matter we seem at length to have within our grasp and obedient to our control the little indivisible particles which with good warrant are supposed to constitute the physical basis of the universe. We have seen that in some of its properties Radiant Matter is as material as this table, whilst in other properties it almost assumes the character of Radiant Energy. We have actually touched the border land where Matter and Force seem to merge into one another, the shadowy realm between Known and Unknown, which for me has always had peculiar temptations. I venture to think that the greatest scientific problems of the future will find their solution in this Border Land, and even beyond; here, it seems to me, lie Ultimate Realities, subtle, far-reaching, wonderful.

“Yet all these were, when no Man did them know,
Yet have from wisest Ages hidden been;
And later Times things more unknowne shall show.
Why then should witlesse Man so much misween,
That nothing is, but that which he hath seene?”

* According to Mr. Johnstone Stoney (Phil. Mag., vol. xxxvi, p. 141), 1 c.c. of air contains about 1000,000,000,000,000 molecules. Therefore a bulb 13.5 centimetres diameter contains $13.5^3 \times 0.5236 \times 1000,000,000,000,000$, or 1,288,252,350,000,000,000,000,000 molecules of air at the ordinary pressure. Therefore the bulb when exhausted to the millionth of an atmosphere, contains 1,288,252,350,000,000,000 molecules, leaving 1,288,251,061,47,650,000,000,000 molecules to enter through the perforation. At the rate of 100,000,000 molecules a second, the time required for them all to enter will be

12882510617,476500 seconds, or

214,708510,231275 minutes, or

3578475,171521 hours, or

149103,162147 days, or

408,50174 years.

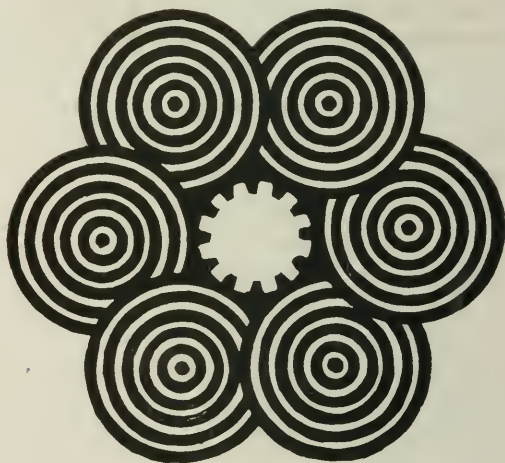
A NEW ILLUSTRATION OF "PERSISTENCE OF VISION."

By THOMAS WILLIAM TOBIN,

Professor of Chemistry and Physics, Central University, Richmond, Ky.

The accompanying optical illusion, described and exhibited by Professor S. P. Thompson, of University College, Bristol, England, has been noticed by many of the European and American scientific journals, as a great curiosity. "If the illustration" (Fig. 1), says the inventor, "is moved by the hand in a small circle without rotating it, or if it is given the same motion that is required to rinse out a pail, the circles will revolve around their centres in the same direction that the drawing moves, and will complete a revolution as the drawing completes its circular motion. The central figure will also revolve, but in the contrary direction.

Fig. 1.



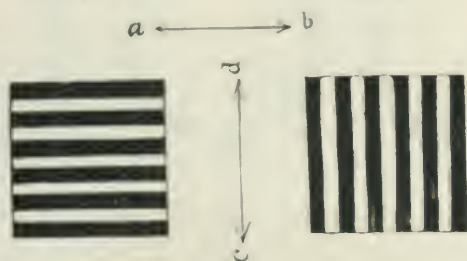
"No satisfactory explanation of these phenomena has as yet been given. It is suggested that the key to the mystery may perhaps be found in the property of the eye which Brewster and others call 'compensation'; that is, the tendency of a repeated or continuous movement to cause a sensation complementary to the real one. For instance, if we gaze at the rocks in a cascade and then at the cascade

alternately, for a short time, the rocks will appear to move upward; or if we examine a stream below a waterfall, the water will appear to flow much faster in the middle than at the sides of the stream. If we look at the middle and sides alternately, the water will seem to flow backward."

This does not afford a satisfactory explanation of the phenomenon. The principle involved is undoubtedly that of "Persistence of Vision," or that property of the retina of the eye, of retaining any image impressed upon it for a perceptible interval of time. This interval of persistence "varies with the sensitiveness of the retina and the intensity of light" (Ganot), and has been found by Pleteau to average half a second.

Fig. 2.

Fig. 3.



Draw a number of thick black lines and equal white spaces intervening, horizontally and vertically, as in Figs. 2 and 3. If now these figures be moved quickly in the directions of the double arrow, *ab*, it is evident that, providing each black line in Fig. 3 replaces the adjacent white line in less than half a second, both images of black and white lines will be superimposed upon the retina, and the effect produced of a grey, indistinct appearance. The same motion will not produce this effect on Fig. 2, as there the similar lines will always superimpose, and the eye will retain the intensities of both black and white lines. Moving the figures in the same manner, but in the directions *cd*, these effects will be reversed, *i. e.*, Fig. 2 will be indistinct, and Fig. 3 bright and intense.

Now, applying these conditions to curved lines and circles, we have the same results; but, as there are no two continuous points in a curve or circle, the intense portions of the lines will be governed by the motion of the figure, and in a circle moved in a circular direction. The

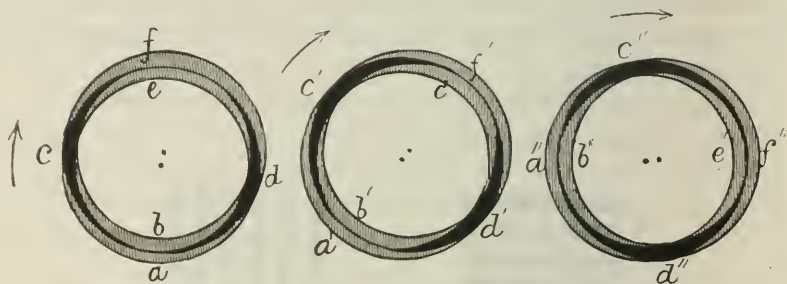
intense portions will partake of the circular motion, as may be explained by the following figures :

Assume that one of the black circles of Fig. 1, and represented by u, c, e, d , Fig. 4, is moved in a circular direction, as indicated by the arrow, if in half a second or less it arrived at the position b, c, f, d , there will be two intense or superimposed portions, c and d , the remainder of the figure being grey, or indistinct.

Fig. 4.

Fig. 5.

Fig. 6.



Let us follow the motion, and after another part of the revolution the circle will be as represented in Fig. 5, and again in half a second from that position the intense portions will be at c' and d' . At a third interval we will find the intense portions, as in Fig. 6, at c'' and d'' , and so on, but continuous throughout an entire circle.

It is the movement of these intense spots over the grey, or indistinct circles that lends the illusion of revolution. In the strict sense of the meaning, the circles cannot appear to revolve, because revolution of a perfect and uniform circle is imperceptible to the eye. It is essential that some prominent part or parts indicate the motion. The parts c and d are made prominent by their intensity, and revolve as shown. The same line of reasoning applies equally to the white as well as the black circles, in regard to their intensities.

This seems to be the rational explanation of the phenomena, which may be verified in a number of consequent experiments, too numerous to describe here.

Artificial Indigo.—Prof. Baeyer, of Munich, has discovered a systematic method for the artificial preparation of this valuable dye.—*Ind. Blätter*.
C.

THE ACTION OF HEAT IN VACUO ON METALS.*

By T. A. EDISON.

In the course of my experiments on electric lighting I have developed some striking phenomena arising from the heating of metals by flames and by the electric current, especially wires of platinum, and platinum alloyed with iridium. These experiments are in progress.

The first fact observed was that platinum lost weight when heated in a flame of hydrogen, that the metal colored the flame green, and that these two results continued until the whole of the platinum in contact with the flame had disappeared. A platinum wire four-thousandths of an inch in diameter, and weighing 306 m.grms., was bunched together and suspended in a hydrogen flame. It lost weight at the rate of a fraction less than 1 m.grm. per hour as long as it was suspended in the flame. When a platinum wire is stretched between two clamping posts, and arranged to pass through a hydrogen flame, it is colored a light green; but when the temperature of the wire is raised above that of the flame, by passing a current through it, the flame is colored a deep green. To ascertain the diminution in the weight of a platinum wire when heated by the electric current, I placed between two clamping posts a wire five-thousandths of an inch in diameter, and weighing 266 m.grms. This wire, after it was brought to incandescence for twenty minutes by the current, lost 1 m.grm. The same wire was then raised to incandescence; for twenty minutes it gave a loss of 3 m.grms. Afterward it was kept incandescent for one hour and ten minutes, at which time it weighed 258 m.grms., a total loss of 8 m.grms. Another wire, weighing 343 m.grms., was kept moderately incandescent for nine consecutive hours, after which it weighed 301 m.grms., showing a total loss of 42 m.grms. A platinum wire twenty-thousandths of an inch in diameter was wound in the form of a spiral one-eighth of an inch in diameter and one-half an inch in length. The two ends of the spiral were secured to clamping posts, and the whole apparatus was covered with a glass shade $2\frac{1}{2}$ inches in diameter and 3 inches high. Upon bringing the spiral to incandescence for twenty minutes that part

*A Paper read before the American Association for the Advancement of Science—Saratoga Meeting.

of the globe in line with the sides of the spiral became slightly darkened; in five hours the deposit became so thick that the incandescent spiral could not be seen through the deposit. This film, which was most perfect, consisted of platinum, and I have no doubt but that large plates of glass might be coated economically by placing them on each side of a large sheet of platinum, kept incandescent by the electric current. This loss in weight, together with the deposit upon the glass, presented a very serious obstacle to the use of metallic wires for giving light by incandescence, but this was easily surmounted after the cause was ascertained. I coated the wire forming the spiral with the oxide of magnesium by dusting upon it finely powdered acetate of magnesium: while incandescent the salt was decomposed by the heat, and there remained a strongly adherent coating of the oxide. This spiral so coated was covered with a glass shade, and brought to incandescence for several minutes; but, instead of a deposit of platinum upon the glass, there was a deposit of the oxide of magnesia. From this and other experiments I became convinced that this effect was due to the washing action of the air upon the spiral; that the loss of weight in and the coloration of the hydrogen flame were also due to the wearing away of the surface of the platina to the attrition produced by the impact of the stream of gases upon the highly incandescent surface, and not to volatilization, as commonly understood; and I venture to say, although I have not tried the experiment, that metallic sodium cannot be volatilized in high vacua by the heat derived from incandescent platinum; any effect that may be produced will be due to the washing action of the residual air. After the experiment last described I placed a spiral of platinum in the receiver of a common air-pump, and arranged it in such a manner that the current could pass through it, while the receiver was exhausted. At a pressure of 2 millimetres the spiral was kept at incandescence for two hours before the deposit was sufficient to become visible. In another experiment, at a higher exhaustion, it required five hours before a deposit became visible. In a sealed glass bulb, exhausted by a Sprengel pump to a point where a quarter of an inch spark from an induction-coil would not pass between points 1 millimetre apart, was placed a spiral, the connecting wires passing through the glass. This spiral has been kept at the most dazzling incandescence for hours without the slightest deposit becoming visible.

I will now describe other and far more important phenomena

observed in my experiments. If a short length of platinum wire one-thousandth of an inch in diameter be held in the flame of a Bunsen burner, at some part it will fuse, and a piece of the wire will be bent at an angle by the action of the globule of melted platinum; in some cases there are several globules formed simultaneously, and the wire assumes a zigzag shape. With a wire four-thousandths of an inch in diameter this effect does not take place, as the temperature cannot be raised to equal that of the smaller wire, owing to the increased radiating surface and mass. After heating, if the wire be examined under a microscope, that part of the surface which has been incandescent will be found covered with innumerable cracks. If the wire be placed between clamping posts, and heated to incandescence for twenty minutes, by the passage of an electric current, the cracks will be so enlarged as to be seen with the naked eye; the wire, under the microscope, presents a shrunken appearance, and is full of deep cracks. If the current is continued for several hours these effects will so increase that the wire will fall to pieces. This disintegration has been noticed in platinum long subjected to the action of a flame by Prof. John W. Draper. The failure of the process of lighting invented by the French chemist Tessie du Motay, who raised sheets of platinum to incandescence by introducing them into a hydrogen flame, was due to the rapid disintegration of the metal. I have ascertained the cause of this phenomenon, and have succeeded in eliminating that which produces it, and in doing so have produced a metal in a state hitherto unknown, and which is absolutely stable at a temperature where nearly all substances melt or are consumed; a metal which, although originally soft and pliable, becomes as homogeneous as glass and as rigid as steel. When wound in the form of a spiral it is as springy and elastic when at the most dazzling incandescence as when cold, and cannot be annealed by any process now commonly known, for the cause of this shrinking and cracking of the wire is due entirely to the expansion of the air in the mechanical and physical pores of the platinum, and the contraction upon the escape of the air. Platinum as sold in commerce may be compared to sandstone, in which the whole is made of a great number of particles with many air spaces. The sandstone upon melting becomes homogeneous and no air spaces exist.

With platinum or any metal the air spaces may be eliminated, and the metal made homogenous by a very simple process. This process I will now describe. I had made a large number of platinum spirals,

all of the same size and from the same quality of wire; each spiral presented to the air a radiating surface of three-sixteenths of an inch; five of these were brought by the electric current up to the melting-point, the light was measured by a photometer, and the average light was equal to four standard candles for each spiral just at the melting point. One of the same kind of spirals was placed in the receiver of an air-pump, and the air exhausted to 2 millimetres; a weak current was then passed through the wire, to slightly warm it for the purpose of assisting the passage of the air from the pores of the metal into the vacuum. The temperature of the wire was gradually augmented, at intervals of ten minutes, until it became red. The object of slowly increasing the temperature was to allow the air to pass out gradually and not explosively. Afterward the current was increased at intervals of fifteen minutes. Before each increase in the current the wire was allowed to cool, and the contraction and expansion at these high temperatures caused the wire to weld together at the points previously containing air. In one hour and forty minutes this spiral had reached such a temperature without melting that it was giving a light of twenty-five standard candles, whereas it would undoubtedly have melted before it gave a light of five candles had it not been put through the above process. Several more spirals were afterwards tried, with the same result. One spiral, which had been brought to these high temperatures more slowly, gave a light equal to thirty standard candles. In the open air this spiral gave nearly the same light, although it required more current to keep it at the same temperature. Upon examination of these spirals, which had passed through the vacuum process, by the aid of a microscope no cracks were visible; the wire had become as white as silver, and had a polish which could not be given it by any other means. The wire had a less diameter than before treatment, and it was exceedingly difficult to melt in the oxy-hydrogen flame. As compared with untreated platinum, it was found that it was as hard as the steel wire used in pianos, and that it could not be annealed at any temperature.

My experiments with many metals treated by this process have proved to my satisfaction, and I have no hesitation in stating that what is known as annealing of metals to make them soft and pliable is nothing more than the cracking of the metal. In every case where a hard drawn wire had been annealed a powerful microscope revealed myriads of cracks in the metal. Since the experiments of which I have just

spoken I have, by the aid of Sprengel mercury pumps, produced higher exhaustion, and have, by consuming five hours in excluding the air from the wire and intermitting the current a great number of times, succeeded in obtaining a light of eight standard candles from a spiral of wire with a total radiating surface of 1.32d of an inch, or a surface about equal to one grain of buckwheat. With spirals of this small size which have not passed through the process, the average amount of light given out before melting is less than one standard candle. Thus I am enabled, by the increased capacity of platinum, to withstand high temperatures to employ small radiating surfaces, and thus reduce the energy required for candle light. I can now obtain eight separate jets, each giving out an absolutely steady light, and each equal to sixteen standard candles, or a total of 128 candles, by the expenditure of 30,000 foot-pounds of energy, or less than one-horse power. As a matter of curiosity I have made spirals of other metals, and excluded the air from them in the manner stated. Common iron wire may be made to give a light greater than platinum not heated. The iron becomes as hard as steel, and just as elastic. Nickel is far more refractory than iron. Steel-wire used in pianos becomes decarbonized, but remains hard, and becomes the color of silver. Aluminum melts only at a white heat.

In conclusion, it may be interesting to state that the melting-points of many oxides is dependent on the manner of applying the heat; for instance, pure oxide of zirconium does not fuse in the flame of the oxy-hydrogen blow-pipe, while it melts like wax and conducts electricity when on an incandescent platinum spiral which is at a far lower temperature; on the other hand, oxide of aluminum easily melts in the oxy-hydrogen flame, while it only vitrifies on the platinum-spiral.

Climatic Influence of Forests.—The meteorological observations of Messrs. Fautrat and Mathieu show that the influence of coniferous trees upon the distribution of rain is twice as great as that of the angiosperms. Pine forests are especially serviceable in the protection of springs and in the prevention of heavy showers and water-spouts. The circulation of air, on account of the differences of temperature above and under the trees, the condensation of vapor, and the cooling influences upon the atmosphere, tend to produce a uniformity of climate similar to that of the sea shore. — *Bayer. Ind. u. Gewerbeblätter*.

C.

THE FORMATION OF COAL.

The paper read by M. Frémy, the eminent Director of the Museum at the Parisian Académie des Sciences, under the title "Chemical Researches respecting the Formation of Coal," is of such great interest that we have no hesitation in making it known to our readers.

It is known that coal is produced by the decomposition of vegetable matter, which for many ages covered the surface of the earth. The learned chemist has made a series of analyses, of which he gives an account in his paper, and which have enabled him to establish the laws of this decomposition, and to explain the transformation of the tissues of the vegetable matter into coal by the loss of their organic form.

With reference to peat, the hypothesis has been put forth generally up to the present time of a possible relation between their formation and that of coal. M. Frémy has been led by the same investigations to the conclusion that the peaty fermentation is, so to speak, the first stage reached by the ligneous tissues before arriving at their complete transformation into coal.

After making these short preliminary remarks, we hasten to introduce M. Frémy in his own words.

The paper, says M. Frémy, which I read to-day on the formation of coal is the latter part of the general investigations on the vegetable tissues which I have carried on since 1850, that is to say, since my nomination to the professorship of the museum.

It is at the Jardin des Plantes that I have found everything needful for pursuing my enquiries into certain matters highly interesting and important to chemistry and vegetable physiology.

The questions which I proposed to myself were as follows:

What is the nature of the elements of which the organs and the tissues of vegetables are formed? Is it possible to discover these elements without altering them, and to determine with some exactness their proportions? Does this chemical analysis of the tissues permit of following the development in the vegetable organization, and of establishing a comparison between them such as science demands? Is it possible for chemistry to make known the exact composition of these elements, at present but imperfectly defined, such as chloro-

phyllus gum, the gelatinous substances of fruits, which are found in a great number of tissues, and which certainly play an important part in the vegetable organization? Lastly, will it be possible, when all these substances are understood, to determine under what influences the tissues of these vegetables are capable of being transformed into fossil fuel, such as lignite, coal and anthracite?

Taking this programme as the basis of my researches, I shall make a rapid survey of those investigations by which I sought to establish the nature and composition of those substances forming the skeleton or framework of vegetable matter.

The organic elements which I first examined were but little known. Their characteristic property is to produce, under the influence of fermentation or by the action of chemical reagents, a series of gummy and gelatinous substances. They may be confounded with the cell-walls themselves when they are merely subjected to microscopical examination. They often join the cells together, as is shown in the tissue forming the pith of the elder tree. I have demonstrated that the gelatinous substances of vegetables are derived from a primal insoluble substance which I have named *pectose*, and which, by successive polymerical transformations, forms at first gummy substances, then gelatinous bodies, and lastly a soluble acid, the strength of which may be compared with that of the acids found in fruits. All these transformations are produced during the growth of the vegetation.

M. Frémy then undertook the investigation of the properties and nature of the stable and fixed bodies forming the fibres, the cells and the ducts. From these researches it results that the vegetable framework is not so simple as was commonly supposed. It is not constituted of a single substance, the cellular variously incrustated with foreign substances, but of several kinds of isomeric cellular substances. In addition to this, a very important body is also met with, which differs from the cellular in respect to its composition and properties, a body which runs abundantly in the ducts, and which M. Frémy has for this reason called *vasculose*. It is this substance which causes the hardness and density of the ligneous tissues to vary according to the proportion in which it is contained. Oak may contain 30 per cent. of it, and as much as 50 per cent. may be found in nutshells. The *vasculose* is placed between the walls of the fibres and the cells, and unites them. It is dissolved by caustic alkalis.

After these internal tissues M. Frémy studied the bodies which

cover and protect them, such as the cuticle. He called by the name of *cutose* the substance which forms the cuticle, and which is even found in cork. It is remarkable for its fixity, and is scarcely affected by sulphuric acid. Lastly, to complete this general study, the learned Director of the Museum examined those bodies which are most frequently met with in the tissues. Gum, for instance, is not a neutral substance, as has been commonly supposed, but a veritable salt, resulting from the combination of a genuine acid with lime. The chlorophyllus itself is not a neutral substance. It is formed of a bluish-green alkaline salt, phyllocyanate of potassa.

These preliminary researches being concluded, M. Frémy placed the top stone to the edifice by attempting the solution of the difficult and interesting problem of the formation of fossil fuel. If vegetable palæontology has made such great progress in these latter times, it may be said that the chemical part of the question has remained in absolute darkness. We know not under what influences the vegetable organization has been destroyed to form this black bituminous mass, partly fusible, non-organic, and insoluble in dissolvents, which constitutes coal. This substance neither resembles the pyrogenous bodies produced in our laboratories nor the ligneous tissues which have formed it. By distillation it gives forth volatile products which do not resemble those given by wood. It leaves also, as a fixed body, a special substance called coke, which is very different from charcoal.

Having already introduced this question in a previous paper, M. Frémy mentioned several chemical reactions which characterized wood, peat, lignite, coal and anthracite. Wood is not perceptibly affected by a diluted solution of potassa, whereas peat often renders to this alkali considerable quantities of ulmic acid. Xyloide lignite, or fossil wood, also contains notable proportions of ulmic acid; but it is not to be confounded either with wood or with peat, because it is transformed into yellow resin by nitric acid, and is completely soluble in hypochlorites. Compact or perfect lignite does not contain any sensible quantity of ulmic acid, but is soluble in nitric acid and hypochlorites. With respect to coal and anthracite, they are characterized by their insolubility in all the neutral solvents, acids, alkalies and hypochlorites.

The experiments of M. Daubrée upon anthracite, and the no less interesting experiments of M. Baroullier upon coal, lead us to think that the transformation into coal is brought about by the action of

heat and pressure upon the vegetable matters. In order to analyze the phenomenon, M. Frémy arranged a series of tests, in which the vegetable tissues, on the one hand, and, on the other, those substances which most frequently accompany them in the organization, were heated to between 200° and 300° for some hours in glass tubes sealed at both ends.

In these experiments M. Frémy observed a great modification. The tissues became black, brittle, and free from water, acids, gas and tar; but they retained their original organization, and furnished a fixed product, offering no resemblance to coal.

The learned academician then submitted to the same test a certain number of bodies produced by organism, such as sugar, starch, gum, etc., and arrived at very different results. These bodies were transformed into substances having a certain analogy to coal: they were black, shiny, often melted, and quite insoluble in acids and alkalis.

The analysis of these bodies, which M. Frémy designates by the name of coally substances, has demonstrated the complete analogy of their composition with that of natural coal. Coal from gum gives in analysis almost the same quantities of carbon, hydrogen and oxygen as natural coal.

From these coincidences of composition M. Frémy draws the conclusion that the elements contained in the vegetable cells—such as sugar, starch, and gum—play an important part in the production of coal.

This result was doubtless a very interesting one; but, in order to complete it, it was necessary to explain how the tissues of vegetables could lose their organic form and produce the amorphous mass called coal. Besides this, also, it was necessary that the tissues should be proved to be capable of undergoing the same coal transformation which was realized by operating upon the non-organic bodies which accompanied them.

The studies of the eminent chemist with respect to lignite and peat now proved of great assistance to him. He had seen in these combustibles the ulmic acid appear in proportion as the ligneous tissues lost their organization. When a peat was adviced he only found insignificant remains of organic tissue, but then it contained from 50 to 60 per cent. of ulmic acid. On examining the fossil wood M. Frémy found pretty thick, black, and shining layers of ulmic acid

proceeding from the transformation of *vasculose* besides the ligneous fibres, which were not yet completely disorganized.

This observation demonstrated the transformation on the spot, and in the ligneous tissue itself, of a part of the wood into ulmic acid. In this way M. Frémy was led to admit the fact which appeared to predominate in his researches, that the vegetable matter was first changed into peat before producing coal, and that in this modification the disappearance of the organic tissues was owing to a kind of peaty fermentation. To confirm this hypothesis he found it necessary to prove that the ulmic acid could, like the bodies previously experimented upon, be transformed into coal.

In consequence M. Frémy studied the transformation of three kinds of ulmic acid, and discovered that, after a calcination of 120 hours, the ulmic acid of the peat was converted into artificial coal, presenting the same composition as the coal of Blanzv.

Lastly, the mixtures of chlorophyllus, fatty bodies and resins obtained from leaves by treating them with alcohol, when submitted to the same operation,—that is to say, heated under the pressure of 150 hours,—produced a black, viscous, odorous substance, insoluble in alkalies, and presenting an evident analogy with natural bitumen.

From these facts M. Frémy draws the following conclusions :

1. Coal is a substance which proceeds from the transformation of vegetable matter, but which no longer preserves its organic form.

2. The vegetable marks which the coal presents are produced by it, as in schist or other mineral substances, and do not prove its organization. This fuel is a bituminous and plastic matter, on which the external features of the vegetation are moulded. When a piece of coal presents on its surface, or within its interior, marks of vegetation, it is not to be thence inferred that the adjacent parts are necessarily the result of the alteration of the tissues which were covered by the membranes whose form has been preserved.

3. The principal bodies contained in the vegetable cells, submitted to the double influence of heat and pressure, produce substances which present the properties and composition of coal.

4. The coloring, resinous and fatty matters contained in the leaves are changed, by the action of heat and pressure, into substances which approach very nearly to natural bitumen.

5. With regard to the ligneous tissues at the base of the *cellulose* and the *vasculose*, they are not transformed directly into coal. Before

being so changed they pass through a process of peaty fermentation, which produces ulmic acid. It is only in the second place that this ulmic acid is transformed into coal, mingling with all the coal-forming substances produced by the contents of the cells.—*L'Houille*.

REGENERATIVE SYSTEM FOR GAS-LIGHT.

Mr. F. Siemens, of Dresden, Germany, like his brother, a prominent electrician and inventor, has published in the *Verhandl. z. Bef. d. Gewerb.* a valuable application of his regenerative system for gas-light. Starting from the fact that the intensity of the light is increased by an increase in the temperature of combustion, he designed a number of different styles of lamps in which the air for the combustion of gas is heated by the waste gases, the supply of air being regulated by the currents produced by the difference of the temperature of the air, the gas and the products of combustion. The lamp consists of three iron tubes of suitable diameters, placed one within the other, the upper portion of the lamp being enclosed in a spherical globe. The entire space inclosed by the different tubes is filled with wire netting, constituting what Mr. Siemens calls regenerators, and which serve for absorbing the heat of the products of combustion and for giving it off to the gas and the air for burning the latter. The central tube is used for conveying the gas, which enters it from below. The air is admitted from below into the annular space between the central and second tube, while the hot products of combustion descend through the annular space between the second and the third tube. By this means the heat absorbed by the wire netting in the outer tube will be conducted and reflected to the two inner ones, and serve to heat air and gas and increase the intensity of the flame. The products of combustion rise upward within the space inclosed by the gas globe, and then descend along its sides, until they reach the annular space of the regenerator, without impeding the flow of air or gas. Mr. Siemens has constructed the lamp in such a manner that the regenerator, having a disc shape, serves as a reflector at the same time. While the construction of these lamps is not such as to make the system readily applicable to single burner lights, it is destined to enlarge or maintain within certain limits the ground which gas has been rapidly losing in its competition with the electric light for the illumination of large spaces.—*Iron Age*.

PATENT METAL JACKET AND MOVABLE BOILER AND PIPE COVERING.

By I. NEWTON PEIRCE.

Read before the Franklin Institute at its meeting, Sept. 17th, 1879.

As early as 1799 among the methods of saving heat and protecting steam from condensation air was tried as a non-conductor. Ever since then "dead," or confined air, has been considered the best non-conducting medium with which to surround steam boilers, steam pipes and hot-blast pipes. The great expense attending the usual methods for accomplishing this, as well as the imperfect manner in which it has been done, has been a serious objection to its general adoption. By this invention the material used is so cheap, the method so simple, its application so easy and the covering so strong and durable that it comes at once within the reach of all using boilers and pipes. In most instances where boilers and their connecting steam pipes are covered by this method the saving in fuel, in five or six months, pays for the entire expense of this covering.

The material used by this method—to make a "dead air space" around the boiler or pipe—is common sheet-iron No. 28. After being cut into desired sizes it is punched all over its surface into small holes, somewhat in the shape of a V, leaving the top of the V attached to the sheet, and then bending it so as to be at right angles with the sheet, at the same time giving this V point a concave or spoon shape, that it may have the greatest possible strength. These pieces of punched sheet-iron are then bent or shaped to fit the boiler or pipe they are intended to cover, sometimes having break-joints in them by which they can be attached to each other. If for a steam pipe, these pieces are about half the circumference of the pipe, with a break-joint on one edge of each, to fit into each other at the top or on one side of the pipe, with the bottom or opposite side overlapping each other. The points of the V's resting against the boiler or pipe keep the surface of the sheet-iron equi-distant in every part from the surface of the boiler or pipe, thus producing and preserving an equal air-space surrounding the boiler or pipe. It then remains to confine this air and prevent any circulation. This is done by covering this metal

jacket with some good non-conducting plastic, or hair, or asbestos, or paper felting. The holes in the sheet-iron afford the best opportunity for any plastic felting to clinch and fasten itself firmly to the metal jacket.

To make this covering a movable one it is only necessary to turn up the edges of the metal jacket about an inch, at right angles to the general surface, in the form of flanges. When placed on the boiler or pipe the flanges are brought closely together and are fastened there by U-shaped pieces of wire slipped over the two flanges, and the plastic or other felting is put on in the usual manner; the flanges protecting the edges from being injured when the covering is handled by being removed and putting on again.

To remove any section of this covering it is only necessary to pull out the wire U's or clamps that are on the flanges of this section, and lift the section off. All the other sections will remain firmly attached, and when put back again and the clamps put in their places the section becomes as firm as at first.

For the purpose of making repairs to boilers, or allowing them to be inspected, this movable feature becomes a very great convenience.

Temperature of the Sun.—Newton, Waterston, Ericsson and Senehi have asserted that the sun's temperature cannot be less than from one to two millions of degrees ($1,800,000$ to $3,600,000^{\circ}$ F.); Pouillet, Vicaire, Violle and many others maintain that the temperature cannot exceed from 1500° to 2500° (2700° to 4500° F.). The French Academy, in 1876, offered a *Bordin Prize* for the solution of the question, which resulted in a reward to Violle, certificates of "honorable mention" to Vicaire and Crova, and a withdrawal of the prize, in consequence of the difficulty and uncertainty involved in the question. Senehi obtained more than $2,000,000^{\circ}$ by Newton's formula, while Violle obtained only 1500° by the formula of Dulong and Petit from the same set of observations. F. Rosetti, in a memoir crowned by the *Royal Academia dei Lincei* discusses experiments and methods of his own, from which he concludes that the temperature cannot be much less than $10,000^{\circ}$ ($18,000^{\circ}$ F.) or much more than $20,000^{\circ}$ ($36,000^{\circ}$ F.).—*Ann. de Chim. et de Phys.* C.

STUDIES ON ULTRAMARINE.

The composition of natural ultramarine is by no means constant. The carbonate of lime found in it by Gmelin to the extent of 28 per cent. belongs to the gangue in which the lazulite is imbedded. Natural ultramarine does not resist alum and acids, but is decomposed by them with liberation of hydrogen sulphide often more readily than are artificial samples. There is consequently no means of distinguishing the natural from the factitious product. Dilute acids decompose artificial ultramarine with the evolution of sulphuretted hydrogen and sulphurous acid. The rose-colored kinds give off sulphurous acid alone. Concentrated sulphuric acid is without action. Hot concentrated solutions of caustic alkalies turn the color from blue to grey. Saturated solutions of alum decompose ultramarine slowly in the cold, but more rapidly with the aid of heat. At about 200° it is converted by acids into a violet ultramarine, which finally becomes red. Ultramarine may be heated to redness without being decolorized, and with certain precautions it may even be incorporated in melted glass, but it begins to be affected at 120° and becomes less brilliant. The complete analysis of ultramarine is very laborious. The author gives here a process sufficient for the requirements of the manufacturer, and showing the silica, alumina, total sulphur and soda. The sample is first decomposed by fuming nitric acid. No sulphuretted hydrogen escapes, and the total sulphur remains in the liquid as sulphuric acid. The liquid is evaporated to dryness, the residue is taken up in a little water acidulated with hydrochloric acid, evaporated a second time, again dissolved in acidulated water, and the silica remaining undissolved is washed with cold water upon the filter. In the filtrate the sulphuric acid is precipitated with barium chloride, when the weight of the barium sulphate shows the total weight of combined sulphur in the ultramarine. Alumina is then precipitated by ammonia, and in its filtrate, after removing baryta by means of sulphuric acid, the soda is determined as sulphate. The properties required by consumers of ultramarine are a deep and brilliant color, fineness, tinctorial power and resistance to alum and to acids. All these points are determined by comparative trials with a standard specimen. Papers or textile materials tinted with aniline-blues on exposure to the sun are bleached often in a few hours. No

other blue employed for this purpose fades so rapidly. Papers, etc., tinted with ultramarine or with cobalt leave a blue ash on incineration. If ultramarine has been used the ash is decolorized by the application of dilute acids, while the shade of cobalt, on the contrary, is brightened by this treatment. Papers, etc., blued with Prussian blue, yield on ignition an ash which gives the reactions of iron.—*Chem. News.*

THE KANE GEYSER WELL.

By CHAS. A. ASHBURNER.

The Kane Geyser or Spouting Water Well, which during the past year has attracted such general attention from the "sight-seeing" public, is no novelty to the oil man. The cause of the action has been so erroneously represented that a correct explanation seems to be demanded.

This well is situated in the valley of Wilson's Run, near the line of the Philadelphia and Erie Railroad, four miles southeast from Kane. It was drilled by Messrs. Grubert and Taylor, in the spring of 1878, to a total depth of 2000 feet. No petroleum was found in paying quantities and the casing was drawn and the hole abandoned, since which time it has been throwing periodically—10 to 15 minutes—a column of water and gas to heights varying from 100 to 150 feet.

During the operation of drilling, fresh "water veins" were encountered down to a depth of 364 feet, which was the limit of the casing. At a depth of 1415 feet a very heavy "gas vein" was struck. This gas was permitted a free escape during the time the drilling was continued to 2000 feet.

When the well was abandoned, from failure to find oil, and the casing drawn, the fresh water flowed into the well and the conflict between the water and the gas commenced, rendering the well an object of great interest. The water flows into the well on top of the gas, until the pressure of the confined gas becomes greater than the weight of the superincumbent water, when an explosion takes place and a column of water and gas is thrown to a great height. This occurs at present at regular intervals of 13 minutes and the spouting continues for 1½ minutes. On July 31st Mr. Sheaffer (aid McKean County) measured two columns, which went to heights respectively of 120 and 128 feet.

On the evening of August 2, I measured four columns in succession, and the water was thrown to the following heights: 108, 132, 120 and 138 feet.

The columns are composed of mingled water and gas, the latter being readily ignited. After nightfall the spectacle is grand. The antagonistic elements of fire and water are so promiscuously blended, that each seems to be fighting for the mastery. At one moment the flame is almost entirely extinguished, only to burst forth at the next instant with increased energy and greater brilliancy.

During sunshine the sprays form an artificial rainbow, and in winter the columns become incased in huge transparent ice chimneys. A number of wells in the oil regions have thrown water geysers similar to the Kane well, but none have attracted such attention. As early as 1833 a salt well, drilled in the valley of the Ohio, threw columns of water and gas at intervals of ten to twelve hours to heights varying from 50 to 100 feet. This well is possibly the first of the "water and gas geyser wells."—*Stowell's Petroleum Reporter*.

DECOMPOSITION OF CHLORINE.

Mr. Fred'k Barkas, of the Zurich Polytechnikum, writes as follows: "A most important chemical discovery has just been made by Herren Victor and Carl Meyer, of the Polytechnikum, Zurich. Herr Victor Meyer had been making a number of experiments to determine the vapor densities of some organic compounds whose constituents were doubtful. Having invented a new and simple apparatus for the purpose, in order to determine its accuracy he made several experiments to test the vapor density of the commoner elements—oxygen, etc.—at temperatures from 100°C. (boiling water) to 1567°C. (heat given by a gas furnace). At length he tried chlorine, which gas was obtained by heating pure dry bichloride of platinum, but the results were not in accordance with theory. When the gas was heated at temperatures under and up to 620°C. it gave a vapor density of 2.46, while theory gives 2.45. This was very good; but at 808°C. the density was only 2.20. At 1028°C. it gave 1.87, while at from 1242°C. to 1567°C. the density remained nearly constant at 1.64 average. From this it was to be inferred that two molecules of chlorine at temperatures above 1200°C. break up into three molecules. Next came the question,

Does this arise from an alteration of the molecular constitution of chlorine, or from an actual decomposition into some new gases; in other words, is chlorine an element? Thereupon the expanded chlorine gas was slowly caused to stream into a fluid that absorbs chlorine. Potassa, iodide of potassium and mercury were all used for the purpose, and with the same result—a gas accumulated in the measuring tube that was not chlorine, but oxygen. Chlorine was thereby proved to be not an element but an oxide of some new element. A number of careful investigations were then made to be sure that the chlorine used was absolutely pure and dry, but with the same result. The new element, hypothetically called *Murium*, has not yet been isolated, but the learned professors are carrying out the important investigation with all diligence, so that doubtless within the course of a few weeks we shall hear more of the new element, *Murium*. That chlorine is an oxygen compound is not altogether a new idea. Sir Humphrey Davy, after his celebrated discoveries of the compound nature of soda and potassa, surmised that chlorine, iodine and bromine were likewise oxygen compounds.

THE SUPPOSED COMPOUND NATURE OF THE ELEMENTS.

By J. NORMAN LOCKYER, F. R. S.

Continuing my researches into the nature of the so-called elements, I have found that when carefully distilled metallic sodium was condensed in a capillary tube, placed in a retort and heated in a Sprengel vacuum, it gave off twenty times its volume of hydrogen. Phosphorus, carefully dried and submitted to the same treatment, gave off 70 volumes of a gas which appeared to consist chiefly of hydrogen. Although it gave some of the lines of phosphorus, it was not PH_3 , as it had no action on solution of cupric sulphate. A specimen of magnesium, carefully purified by Messrs. Johnson and Matthey, gave me a magnificent series of colored phenomena. The hydrogen lines first appeared, then the D line—not the sodium line, be it understood, for the green line was absent—and, lastly, the green line of magnesium (*b*), and then, as the temperature was increased, mixtures of all these lines, with the blue line, the D line being always the most brilliant. In this experiment

only two volumes of hydrogen were collected. From gallium and arsenic no gas of any kind was obtained. From sulphur and some of its compounds sulphurous anhydride was always obtained. From indium hydrogen was given off in vacuo before heating, while from lithium no less than 100 volumes of hydrogen were given off. The conditions of the experiments were always the same, the only variable being the substance itself.—*Proceedings of British Association.*

PHOSPHORECENT PHOTOGRAPHS.

To Mr. Woodbury's inventive ingenuity we owe this plan, which has been tested, and is a practical success. The method he employs is known as the "dusting-on" process. It consists in coating a plate with a preparation of dextrine, honey and bichromate of ammonia, which, exposed under a negative, becomes hardened, where it is subjected to the action of light, through the transparent parts of the negative, remaining tacky where it is protected from the action of light by the denser parts of the negative. After exposure under a negative, the film, as it will be seen, is tacky in the lights of the picture, but hard and dry where light has acted on the shadows. The lights are therefore adhesive and tacky, retaining any fine powder which is dusted in or rubbed into the moist surface. At this point comes in the essential novelty. The powder to be used must be a phosphorescent substance. One of the best known and available is sulphide of calcium. A powder of this substance is applied to the image formed on the adhesive film, and sticks to it in due gradation of the tackiness, as regulated by the action of the light which passed through the negative. An image of sulphide of calcium is thus formed, which, the powder being nearly white, is scarcely visible by daylight, but if the image be submitted for a time to sunlight, or bright daylight, or brilliant artificial light, and then taken into the dark, presents a luminous picture, somewhat startling, indeed, in the case of a portrait. A variety of substances possess this phosphorescent quality: sulphides of barium, calcium and strontium displaying it in the most marked degree; fluorspar, carbonate of lime, pearls, diamonds, phosphate of lime and arseniate of lime.—*Telegraphic Journal.*

Vibratory Forms of Circular Plates.—C. Decharme has extended the investigation of nodal systems, and drawn some interesting comparisons with the earlier researches of Chladni, who indicated three systems of nodal lines: the diametral, the concentric and the compound. He substitutes a thin layer of water or some similar liquid for the sand which Chladni employed, and finds many interesting relations among the peripheral and eccentric networks, the number of sonorous vibrations, the breadths of the striae, the areas of the inter-nodal sectors, and the numbers of nodal divisions. By means of these equations it becomes easy to estimate the wave lengths of different sounds.—*Ann. d. Phys. und Chem.* C.

Improvements in Calculating Machines.—Staffel has invented an arithmetical machine in which three cylinders are so arranged that they can work all the simpler rules of arithmetic, carrying multiplication up to millions by millions; if the machine is required to solve an impossible sum, such as subtracting a larger number from a smaller, or dividing a smaller sum by a greater, it refuses, and rings a bell as an admonition. Colmar invented an arithmometer in which the action is rather by plates sliding in grooves than by rotating cylinders; like Staffel's it can perform addition, subtraction, multiplication, division and evolution. Wertheimer, by means of a metal plate with indexes, notches, teeth and holes, has contrived an apparatus for adding and subtracting sums of money. Baranowski's invention is for calculating wages, prices, interest and other sums of money; it is known as the Ready Reckoner, and is worked by means of a handle which reveals figures or numerals in openings in a brass plate. Schott, Lalanne, Roget, Maurel, Roth, Slovinskis and Scheutz have in like manner invented machines for solving arithmetical problems. Of these, Scheutz's excites great admiration among scientific men; Mr. Babbage highly extolled it, and deplored that it had found a purchaser in America instead of in England. It can compute mathematical tables, calculate to sixteen places of figures, and stamp on a plate of lead the result up to eight places, producing a matrix or mould from which a cliché cast in type metal can be obtained, suitable for printing from; it does its work at the rate of twenty-five figures or numerals per minute, calculated, recorded and stamped in metal—an error either in the calculating or the printing being almost impossible.

Non-explosive Collodion.—Dissolve in alcohol and ether pure, well-washed gun-cotton; filter thoroughly and distil off the ether and alcohol until the thick residuum can be cast, while still warm, into moulds. After cooling, cut the gelatinous mass into bits, and dry them by evaporating the remaining alcohol. Dissolve again in alcohol and ether and the collodion will be neither explosive nor subject to spontaneous combustion.—*Chem. Ind.* C.

The Mineral Wealth of Great Britain.—The mineral wealth of Great Britain is shown by the fact, as officially stated, that the product of coal was, in 1877, 134,610,763 tons, as against 133,344,766 tons in 1876; of iron ore the product was 16,692,802 tons, against 16,841,583 the previous year; lead ore, 80,850 tons against 79,095 in 1876; tin ore, 14,142 tons, against 13,688 in the year before; copper ore 73,041 tons, against 79,252 in 1876, and salt, 2,735,000 tons. The total value of minerals and metals obtained from the mines, etc., of the United Kingdom in 1877 reached £68,281,405, viz.: £18,742,960, the value of the metals; £47,113,767, coal, and £2,424,679, minerals, earthy, not reduced, together with the value of salt, clays, etc. But the great item in these returns is the vast quantity—6,608,664 tons—of pig iron, of the value of more than \$80,000,000, and it is estimated that in the manufacture of this metal between 15,000,000 and 16,000,000 tons of coal were used.

Molecular Constitution of Liquids.—R. Pictet has shown that in solid bodies there is a simple relation between their atomic weight, their length of calorific scintillation, and their temperature of fusion. This relation is a consequence of the universality of the laws of attraction, and of the most simple representation of the temperature, regarded as the *amplitude* of the calorific oscillations. On passing from the solid, to the liquid state, each solid molecule should contain at least two liquid molecules. Since the molecular cohesion of all bodies is equal at the melting point, on departing from that point the lengths of calorific oscillation should be functions of molecular masses for equivalent aberrations of temperature. If we compare all liquids at their boiling points we should be able to deduce the same numerical formula as for solids. Pictet confirms these views by a comparison of theoretical and observed results in twenty-three solids and sixteen liquids.—*Comptes Rendus.* C.

Number of Oscillations in a Musical Note.—Pfändler concluded, from observations with a siren, that two oscillations were sufficient to produce a note. Felix Auerbach, from a combination of physiological, psychological, physical and musical considerations, finds that probably about twenty oscillations are necessary. His views are confirmed by previous observations of Exner, Von Kries and Toepler.—*Ann. der Phys. und Chem.* C.

Large Map of the Solar Spectrum.—M. Thollon has exhibited to the French Academy a map of the visible portion of the solar spectrum, carefully executed in Italy, with the help of his large spectro-scope. It is 10 metres (32·809 ft.) long, extending from A to H, and exhibiting about 4000 lines. Angström's map contained 1600 lines, and was 3 metres long. He calls special attention to the singular resemblance between the groups A and B, which never before have been so completely resolved, and proposes the following classification of lines: 1. Lines formed by a nebulosity without nucleus. 2. Lines consisting of a nucleus without apparent nebulosity. 3. Lines having both nucleus and nebulosity, the latter predominating. 4. Lines having nucleus and nebulosity, the former predominating. He gives a description of his apparatus, and states that the only precaution necessary in using it is to guard the prisms carefully from any variation of temperature.—*Comptes Rendus*, C.

Mechanical Operation of Sound-Waves.—K. H. Schellbach and E. E. Boehn have experimented with waves of sound, in illustration of the wave theory of light. Connecting two Leyden jars with the conductors of a Holtz electrical machine, so as to produce sparks of 1 centimetre (·39 in.) between the balls of the discharger, concentric rings were formed in coal-dust sprinkled on a glass plate 4 centimetres (1·57 in.) from the balls. The longer the spark the more strongly marked were the rings. By reflecting the reports of the discharges, by means of parallel walls and mirrors of various kinds, the dust-waves were made to assume such forms as are theoretically deducible from the reflection and refraction of light, thus visibly confirming the views of Huyghens and Young. That the results are not modified in any way by mere electrical action can be readily shown by substituting explosive gas or powder for the sparks. From ten to twenty sparks or explosions were generally sufficient to show the character of the waves and of their nodal intersections.—*Ann. d. Phys. und Chem.* C.

Proportion of Carbonic Acid in the Air.—The chemical text-books, almost without exception, hand down the classical and quasi-official assertion, that the atmospheric air contains a small quantity of carbonic acid, varying usually between 4 and 6 ten-thousandths in volume. On examining the reports of the most careful experimenter we find nothing to justify this narrow limitation; under the same meteorological conditions, at intervals of a few hours, the figures are often doubled. J. Reiset has experimented in open fields, far from any dwellings, with aspirators containing about 600 litres (158·51 gal.), and with ingenious precautions for securing the utmost possible accuracy of results. He never found so large a proportion of carbonic acid as 4 ten-thousandths. The range, in his summary, is between 2·829 and 3·178, and the mean 2·942 ten-thousandths. In the rue de Vigny, near the Parc Monceau, Paris, during the month of May, the mean of three years' observations was 3·027 ten-thousandths. The extreme variations did not exceed ·00003. In order to study the relations between these variations and the states of the atmosphere it would be necessary to use methods which would give results true to ten-millionths.—*Comptes Rendus*. C.

Franklin Institute.

HALL OF THE INSTITUTE, Oct. 15th, 1879.

The stated meeting was called to order at 8 o'clock P. M., the President, Mr. William P. Tatham, in the chair.

There were present 125 members and 53 visitors.

The minutes of the last meeting were read and approved.

The Actuary presented the minutes of the Board of Managers, and announced that, at the last meeting, six persons were elected members of the Institute, and reported the following preamble and resolutions passed by the Board.

WHEREAS, We have learned with deep regret the death of our fellow member and Vice-President of the Franklin Institute, Mr. CHARLES S. CLOSE, therefore

Resolved, That by this event our Institute has lost an earnest and most efficient officer, and the community a most valuable citizen.

Resolved, That we offer our condolence to his bereaved family, and will attend his funeral at the appointed hour.

Resolved, That these proceedings be entered on our minutes and be published.

The Secretary reported the following donations to the Library :

Second, Fourth, Ninth to Sixteenth, Twentieth to Twenty-eighth Annual Reports of the Spring Garden Institute, Philada.

From the Institute.

Reports of the Principal and Professors of the Imperial College of Engineering. Tokyo, Japan. From the Smithsonian Institution.

Reports upon the Survey of the Boundary between the territory of the United States and the possessions of Great Britain, with one Atlas. From the Secretary of State, Washington.

Report upon the U. S. Geographical Surveys west of the 100th meridian. Vol. 5. Botany.

From the Chief of Engineers, Washington.

Transactions of the Institution of Civil Engineers of Ireland. Vols. 1—9 and Vol 11, in 13 parts. From the Institution.

First Biennial Report of the State Board of Agriculture for 1877—8. From A. Gray, Secretary.

Annual Reports of the State Board of Health of the State of Michigan. For 1874—1878.

Lecture on Healthy Homes for Farmers. By K. C. Kedzie, M. D. From the State Board of Health.

Report on Life-Saving Apparatus. From the Chief of Ordnance.

Annual Report of the Secretary of Internal Affairs of the Commonwealth of Pennsylvania. Part 4. From A. H. Dunkel, Secretary.

The Compendium of Architectural Sheet-Metal Work, Salem, Ohio, 1876. From Dr. W. H. Wahl.

Documents relating to the History of the Dutch and Swedish Settlements on the Delaware River. By B. Fernow. Vol 12. Albany.

Eighty-eighth Annual Report of the Regents of the University of New York.

Sixty-first Annual Report of the Trustees of the New York State Library.

Thirtieth Annual Report on the New York State Museum of Natural History. By the Regents of the University of New York.

Principle of Least Action in Nature. By Samuel Houghton.

Programm der Polytechnischen Schule zu Carlsruhe.

A Series of Familiar Lectures on the Elements of Scientific Knowledge most required in Daily Life. By Thos. Twining. Parts 5 and 6. London. From the Smithsonian Institution.

Proceedings of the Twenty-seventh Annual Meeting of the Board of Supervising Inspectors of Steam Vessels. From the Board.

Twenty-seventh Annual Report of the Trustees of the Public Library, Boston. From the Library.

Steam Engine. By W. Conte. Troy, New York. From the Author.

Examination of the North Carolina Uranium Minerals. By F. A. Genth. From the Author.

Fifty-eighth Annual Report of the Board of Direction of the Mercantile Library Association of New York. From the Association.

Obituary Notice of Isaac Hays, M. D. By S. D. Gross, M. D. Philadelphia.

Fourth Report of the Board of Trustees of Public Schools of the District of Columbia. From the Board.

Recent Accessions to, and Annual Report of, the Astor Library. From the Library.

Annual Report upon Explorations and Surveys in the Department of the Missouri. By E. H. Ruffner. From the Chief of Engineers, Washington.

Distribution of Heat in the Spectra of various sources of Radiation. By W. W. Jacques. From the Author.

Report of the Select Standing Committee on Immigration and Colonization. Ottawa, Canada.

Beiträge zur Beleuchtung der Allgemeinen Verhältnisse der Oesterreichischen Eisenbahnen. Wien. From M. Ritter von Pischhof.

Eighth to Tenth Annual Reports of the Geological Survey of Indiana, made during 1876—1878. By E. T. Cox. From John Collett, Chief of Bureau of Statistics and Geology.

Lessons in Cookery. By E. A. Youmans. From M. L. Dods.

Reports upon the Specimens obtained from Borings made in 1874, between the Mississippi River and Lake Borgne.

On the Use of the Barometer on Surveys and Reconnoissances. From the Chief of Engineers.

State of Labor in Europe. Reports from the U. S. Consuls in the several Countries of Europe on Rates of Wages. From the Secretary of State, Washington.

Fifty-seventh and Fifty-ninth Annual Reports of the Managers of the Apprentices' Library Company of Philadelphia.

From the Company.

Historical Records of Port Phillip. By J. J. Shillinglaw.

From W. H. Odgers, Melbourne, Victoria.

Bulletin of United States Geological and Geographical Survey of the Territories. Vol. 5, No. 1.

From the Secretary of Department of the Interior.

Geological Survey of Canada. Mesozoic Fossils. Vol. 1. By J. F. Whiteaves. Montreal.

From the Geological Survey of Canada.

Meteoric Fireballs seen in the United States during the year ending March 31, 1879. By Prof. Daniel Kirkwood. From the Author.

Fifth Annual Catalogue of Central University, Richmond, Ky.

From Prof. T. W. Tobin.

Report to His Excellency the Governor, of the Thirty-seventh Missouri Catalogue.

From the University.

Annals of the Astronomical Observatory of Harvard College. Vol. 11, Part 1. By E. C. Pickering.

From the College.

Commissioners of Patents Journal. July, 1 and 4.

Abridgments relating to Lacc-Making, Knitting, etc. London.

" " Cutting, Folding, etc., Paper. "

" " Agriculture. Division 2. "

" " Letterpress and similar Printing. "

" " Printing. "

Drawing, No. 2745 of 1878.

Specifications Nos. 3050, 3051, 3052 of 1807; No. 5633 of 1828; No. 12,430 of 1849; No. 2995 of 1860; No. 1082 and 2118 of 1864; No. 2620 of 1867; No. 2784 of 1876.

Disclaimers No. 385* of 1876; No. 3256 of 1877; and No. 995* of 1878.

Subject-Matter Index of Patents Applied for and Patents Granted. London.

Alphabetical Index of Patentees and Applicants for Patents of Invention. London.

Specifications and Drawings. Vols. 22, 25—38. London.

From the Commissioners of Patents, through Mr. Fredk Runsome.

Mr. H. P. M. Birkinbine read a paper on the "Future Water Supply of Philadelphia," and some remarks were made on the subject by Mr. Thomas Shaw.

Mr. Jawood Lukens read a paper on an "Improved Puddling and Heating Furnace," of which he is the inventor, and diagrams of it were thrown upon the screen.

Mr. Bilgram explained the Improved Wire Sewing Machine for books, illuminated diagrams being used; and a machine in operation was also shown, Mr. Lever giving a number of practical details, and exhibiting samples of the work.

The Secretary's report included new forms of Meaker's automatic coin cashiers and money trays, rubber scrubbing brushes, and patent shawl straps. A number of beautiful photographs were exhibited, of Krupp's great establishment at Essen, and of the guns he has manufactured at different times, the gift of Mr. A. G. Buzby to the Institute.

Mr. Robert Briggs read the following memorial of our late Vice-President, Mr. CHARLES S. CLOSE, which, on motion of Mr. Weaver, was ordered to be printed in our minutes.

CHARLES S. CLOSE was born in the old city of Philadelphia, on the 20th of April, 1817. His father, a seafaring man, was mate of a vessel at the time of his death, in 1827, when the mother was left with little means of support for herself and family of four small children, of whom Charles, the subject of this memoir, was the eldest. A common school education of no high order at that time in the city of Philadelphia, which terminated at the age of ten years, when his father died, was all the education which the future master builder and member of the Board of City Surveys received for his commencement in life.

For three or more years he had employment in various ways, one of which was as an errand boy in a printing office, where he mastered the art of working the hand presses and became proficient as a ball boy. At the Exhibition of the Franklin Institute in 1874, as an indication of the progress of the art of printing, some presses of forty years before were shown. They were operated with much *eclat* by the venerable Mr. Hector Orr and Mr. CLOSE after the method of their time. Mr. Orr was foreman in the printing office of Charles Alexander, where the boy CLOSE was employed.

About 1834 he was apprenticed to learn the trade of a house carpenter to a Mr. John Countiss of the city of Philadelphia. At the end of three or more years the indentures were cancelled by agreement, for reasons entirely creditable to the young man. While under the pupilage of Mr. Countiss, however, young CLOSE became an excellent workman, so that before he was twenty years of age he received the highest wages paid journeymen.

He has been known to say that when he left school he could only do a sum in long division, but he had an early love for books and studious habits, and he bought all he could and studied to educate himself in the practical way as a builder and constructor. Some friend in the seafaring line interested him in nautical matters and gave him some instruction in elementary navigation. With an excellent constitution, perfectly abstemious habits, a quick wit which gave expression to a hearty enjoyment of every thing properly enjoyable, and with aspirations to learn and a will to perform, he was, in his young days, a companion for any around him, and a leader of men.

During his minority his small earnings and savings were absorbed by the wants of the family, so that his acquisition of knowledge, which formed the foundation of his future success, was made under many difficulties. To the end of her life he was an affectionate son and the chief reliance and support of his mother, whose efforts and sacrifices in his behalf in the time of his youth he often recalled.

About 1839 or 1840 Mr. CLOSE went to Mobile to find employment as a carpenter, but his stay was very brief. Fortunately or unfortunately he acceded to the request of a bright negro to show him the letters of the alphabet, which he did publicly, but yet with the then inevitable result, that it was desirable for the teacher to return to the North with some promptness. The return voyage to Boston brought out a curious instance of the advantage of general information.

The captain of the bark *Coosa* became insane on the passage; the mate proved utterly incompetent as a navigator, and the crew, with the two or three passengers, elected Mr. CLOSE captain, as the only one acquainted at all with navigation and knowing how to handle the vessel. Capt. CLOSE brought the vessel safely to Boston harbor [on a winter run]. Shortly after this time Mr. CLOSE went to Brazil with intention of settling, but although his prospects were very bright, continued illness induced him to return to Philadelphia.

About 1843 he became established as a carpenter and builder in the district of Southwark, and in that year he completed his first contract. Business grew rapidly upon him, and although he never took large contracts, he quickly had a remunerating business in its way.

In 1849, May 4th, he was elected Surveyor and Regulator for the district of Southwark. At this time he had never made a survey, nor is it probable he had ever used, much less owned, an instrument—level, surveyor's compass or transit. His fitness to accomplish anything he could be induced to undertake was thus generally admitted, and there were some special reasons why his fellow citizens thought it desirable he should take this unsought-for place. With one interval of five years, when some political causes effected a change, Mr. CLOSE has been elected and has held the office of Surveyor and Regulator of Southwark, or the corresponding district in the southern part of the city of

Philadelphia, for thirty years. The surveys and grades of the district when he commenced were in great confusion; under his direction and mostly by his own hand they have been completely revised and established. There is now no question possible as to the competency of Mr. CLOSE as a skilled surveyor. When Mr. CLOSE became Surveyor of the District he in great degree gave up his direct business as a contracting builder, and in course of a few years had a practice, more or less extended, as an engineer in construction of several kinds; in this way he was very successful in planning and directing work.

As a business man he has been eminently prosperous, and he became a considerable property holder in the southern part of the city. He has been President of the Seventh National Bank of this city the past four or five years.

Mr. CLOSE joined the Franklin Institute in 1855, was elected a member of the Board of Managers in 1864, and has been Vice-President of the Institute since 1875.

Mr. CLOSE frequently, of late years, attributed to the instruction imparted by the lectures and at the meetings of the Franklin Institute his acquisition of knowledge which so elevated him in his place as a working man, and often expressed his devotion to the interests of the Institute, saying that only in that way could he repay his indebtedness.

He was a man to whom life was thoroughly enjoyable, unruffled by petty annoyances, above any suspicion of meanness, intolerant only of any pretence, he enjoyed the respect and affection of all who knew him. Unassuming himself, he resented nothing but assumption by others, and his resentment evaporated in the words with which he would happily rebuke any impropriety. Integrity was associated with every thing he did or allowed to be done, with every undertaking with which he was connected. Mr. CLOSE was a liberal man; no charity or beneficence failed to receive his sympathy and support with the largest liberality in money, and his time was always given freely for such purposes. He was associated with all the charities and public enterprises of his section of the city.

In his family he was very happy, and of those who knew him—an almost innumerable number—all were warm friends and associates, holding his company in high esteem.

He died on the 10th of October, 1879, at his residence on Reed Street, regretted by all, and especially by the members and officers of the Franklin Institute, with whom he had been so long connected.

Mr. Hector Orr offered resolutions of regret at the death of Mr. CHARLES S. CLOSE and Mr. HENRY C. CAREY.

On motion, the meeting adjourned.

ISAAC NORRIS, M. D., *Secretary pro tem.*

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UPON A NEW THEORY OF THE RETAINING WALL.*

By A. J. DU BOIS, PH. D.,

Professor of Dynamic Engineering in the Sheffield Scientific School of Yale College.

I wish in what follows to direct attention to a new theory of retaining walls, lately published by Prof. Weyrauch, of the Stuttgart Polytechnikum, in the "Zeitschrift für Baukunde," Band I, Heft 2, 1878.

The subject of retaining walls is one of special interest to the engineer and constructor. It is perhaps one of the most fertile subjects of discussion which come up for "periodical settlement" before engineering societies, and yet the subject does not seem ever to get settled. Every engineer knows, or thinks he knows, how to build a retaining wall, and yet nearly every engineer has a different theory as to how the wall should be proportioned. Perhaps no subject of applied engineering science has been so plastered over with theory and counter theory, and perhaps it is not too much to say that the treatment of no other subject has consequently brought upon applied mathematics so much opprobrium from the side of the so-called "practical engineer," who, disregarding all the abstruse formulæ and learned reasoning with which the subject has been encumbered, finds that with the aid of eyes and expe-

* Paper read before the New Haven Engineering Society, Oct. 25, 1878.

rience he can build, under any given circumstances, a very satisfactory wall without such help.

Hence he is prone to ask, and in such cases not indeed without reason, "What is the use of all this mathematical rubbish, anyhow?" and comes to make a practical, even if erroneous, distinction between "theory" and "practice" and to look with distrust upon the discussion of any case which involves the mysterious and all-pervading "x" and "y." That this is true with regard to many subjects of engineering science I think few will dispute. That it is especially true in the present case will, I think, be apparent.

Few engineers, however, need to-day to be told that the mathematics are only an aid to the reasoning faculties, enabling one to follow out to perfectly logical consequences a train of reasoning which would otherwise elude the grasp of the best trained mind. That they are an instrument merely, a means to an end, and that guiding intelligence and reason must ever control the mechanism. That "theory" is thus only the best reasoning of which we are capable by the use of all those aids which human ingenuity has given us, and is always just as true as its data, neither more nor less. That "practice" is, when worthy, always based upon such reasoning, and differs, if at all, only in that it does not make use of such aids generally or to such an extent, and is hence, if any distinction is made, rather more open to error in its conclusions, and not, therefore, *always* as true as its data.

In the validity of the data assumed, lies the strength of both, and the true reason of any popular distinction between them. Practice built up upon false data is but poor theory, and theory based upon false facts leads to bad practice. The "practical" engineer of to-day is, in common parlance, distinguished from the "theoretical," if at all, mainly by the superior accuracy of his data, drawn as they are from actual experience, and by his therefore superior comprehension of the practical bearings of any given problem, while he is often deficient in his logical methods. The theoretical engineer, on the other hand, although often possessed of superior accuracy in his logical methods, is handicapped by the lack of that experience necessary for a proper comprehension of the data essential to any given problem. Supply the defects of each and the distinction ceases to exist. Such a distinction the work of our technical and scientific institutions tends to render yearly less and less apparent and valid, and, from this point of view, the presenta-

tion of a problem, the history of which emphasizes very strongly the above remarks, cannot fail to be interesting and instructive.

I say the history of this problem of the retaining wall emphasizes well the above distinction between the theory and practice of engineering as represented by the engineers of to-day. For although, as I have said, the mathematician has devoted special attention to its solution, the history of every such attempt shows conclusively that the proper data have been disregarded, and premises have been assumed not warranted by facts. Here, then, is a lesson for many of us, viz.: to scrutinize closely our first assumptions and data before we set the mathematical machine at work, and never to forget that every result it grinds out is, after all, based upon an "if". If we put in error we cannot expect it to turn out truth.

This caution has not always been exercised, and the erroneous results are, and have been, taken by the practical engineer into his daily work, and have of course been found not in accord with fact. Hence a distrust in some directions of all theory and a falling back upon blind precedent and rules of thumb, than which nothing can be more fatal to all engineering progress. Here, then, we learn a second lesson, viz.: to remember that a formula holds good only under the same practical conditions as those assumed in its development, and can never be safely used except by one who thoroughly appreciates the premises upon which it is based.

Now let me endeavor to illustrate the above remarks by a brief history of what has been done by mathematicians upon this vexed problem of the retaining wall. Only in the light of such a review can we properly estimate the value and the points of difference of any proposed new theory. We shall first, then, pass in brief review the various solutions and point out wherein they fail to properly represent the case. For this purpose we shall not need to go into details or give results. It will suffice to confine our attention closely to the various assumptions upon which all former theories have been based.

In a small but exhaustive work by Prof. Winkler, entitled "*Nene Theorie des Erddruckes*," Wien, 1872, quite a full history of the various theories which have been proposed will be found. We shall condense from it, in what follows, as much as will serve our purpose, pointing out the fallacies of each theory as we proceed, including that of Prof. Winkler himself, as noticed by Prof. Weyrauch. We shall then briefly give the theory of Prof. Weyrauch and its results. Such a

course will enable us to properly estimate the value of these results and the real advance constituted by the new theory. My object will be attained if I succeed in calling general attention to this new theory and producing the conviction that Prof. Weyrauch, with characteristic acuteness, has hit the weak spot in all the hitherto accepted theories, has remedied it, and has thus produced a theory free from the defects of all preceding ones—a theory and, so far as I know, the only theory thus far propounded, which is based upon sound data, and which can therefore be considered as reliable.

I. HISTORY OF THE SUBJECT.

Following, then, for the present, the history of the subject as given by Prof. Winkler in his *brochure* already referred to, two methods may be followed in determining the earth pressure upon a confining wall. According to the one, we consider a certain finite wedge-like portion or so-called “prism of rupture,” which tends to separate from the rest of the earth and overturn or slide the wall; and, according to the other, we may consider the conditions of equilibrium of the earth particles and arrive at the total pressure by integration.

The first method is that which has generally been followed, and to it, therefore, we shall chiefly confine our attention. This method, that of the prism of rupture, we may, in view of what has been done, divide into two sub-methods.

I. The position of the surface of rupture is *à priori* assumed—ordinarily the same as the surface of repose.

II. This surface of rupture is determined under such conditions as make the earth thrust a maximum.

At first it was customary to assume this thrust as perpendicular to the wall, or, in other words, *friction was disregarded*. Later on it was recognized that this pressure, owing to friction, could not, in general, be perpendicular to the wall.

In all theories the surface of rupture is assumed to be plane, and the effect of cohesion is generally disregarded.

Let us now review briefly,

I. THE OLDER THEORIES.

These we may state as

1st. *Theories which assume the natural slope as the surface of rupture—friction being disregarded.*

That is, the weight of the prism of rupture is decomposed into components parallel and normal to the natural slope.

Under this head we have the theories of Vauban (1687), Bullet (1691), Couplet (1727), Salomonmyer and Rondelet (1767), Tersac de Montlong (1774), and Blaveau (1767).

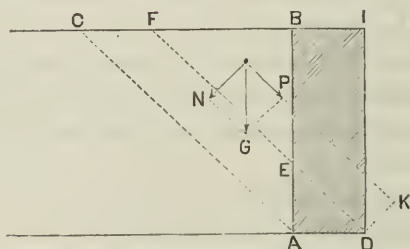
The French General Vauban was the first to treat retaining walls in his "*Traité de la defense des places*," in 1687. It is doubtful whether he was guided at all by theoretical considerations. If so, it is not known what they were.

Bullet, in his "*Traité d'architecture pratique*," 1691, gives a primitive theory. He assumes the prism of rupture as bounded by a plane at an inclination of 45° , and decomposes its weight into parallel and perpendicular components. The parallel component he assumes to act directly upon the wall. He divides this by the height to get the thickness.

I need hardly point out the error of each and all of these assumptions. The inclination of the surface of rupture every practical engineer knows of his own experience, varies with the kind of material, the inclination of the wall and the slope of the ground. To assume it as constant, is to beg the whole question and to insert in the mathematical machine an assumption not warranted by fact. Of course, the results deduced are not then true, and are valueless. The method is an illustration of a tendency, perhaps not yet entirely eradicated, of assuming data carelessly, without sufficient regard to natural conditions and then building up an elaborate mathematical superstructure upon such shaky foundations. The same may be said of the decomposition of the weight of the assumed prism of rupture into parallel and perpendicular components, thus disregarding entirely the effect of friction. The division of the thrust by the height, in order to obtain the thickness, is again a pure assumption, which would invalidate the rest, even were it all true.

Couplet (1727) differed from Bullet only in taking the surface of rupture through the forward edge of the wall D , assuming the angle to be that made by a pile of balls, or the tangent of the angle of inclination of EF to be $1.8 = 2.83$, assuming $AEFC$ to be supported by the portion of the wall ADE , and also in equating the moment of the thrust P about D to the moment of the weight of the wall. The deviations are improvements, but the whole method is open to the

same objections as Bullet's. The assumption as to the angle of repose shows an advance, in that it has reference to nature in some degree, and is not wholly drawn from "inner consciousness."



Sallomyer and Rondelet (1767) followed Couplet in every respect, except that they took the surface of rupture through the rear edge, *A*, of the wall instead of *D*. They contributed, therefore, nothing, and practically no advance has yet been made by any one.

Tersac de Montlong (1774) simply returned to the 45° angle of Bullet, and only modified the views of Couplet and Rondelet by assuming the portion of *AEEC* to revolve the wall in one direction and the portion *EBF* in the other. The difference is of course only apparent, for the combined action is the same as that of *ABC*, and we have, therefore, Bullet's theory in fact.

Blaveau (1767) only differed from Bullet in that he decomposed *P* into a horizontal component, *H*, and a vertical component, *V*, and took the first as the pressure upon the wall. Still nothing is gained. No wonder that practical engineers should regard with distrust mathematicians producing such theories as these! Any man face to face with a bank of earth for the first time could detect the main error of these theories. "The parallel component," he might say, "is indeed the force which would slide the prism down along the surface of repose if there were no wall to retain it, but this force is opposed by friction, and in the case of the natural slope is just equal to the friction, so that there is nothing left to cause pressure upon the wall. Moreover, the angle of repose is incorrectly assumed." And such a position would be fully justified. What, then, have we thus far gained? Nothing but vexation of spirit for the practical engineer who wishes some better rule than a "rule of thumb," and masses of bristling formulæ to dismay the heart and confuse the mind of the docile and much-enduring student of engineering science.

A step forward was made by Coulomb in 1774, by the assumption

of a prism of greatest thrust, and yet, strange to say, we find even in recent times a return to the old exploded theories just mentioned, by Maschek, in 1842, and Hoffmann, in 1858. Hoffmann rejects the prism of greatest thrust, without giving any reason for so doing, takes the surface of rupture through the forward edge for rotation, and through the rear edge for sliding, and decomposes in the latter case the parallel component into horizontal and vertical components. His theory thus has something in common with that of Couplet and of Blaveau, and is in no sense superior to either.

Thus we see that revivals of old and exploded theories are to be guarded against even now. A knowledge of what has been done in the history of the subject will enable us in any such case to relegate at sight all such revivals to their proper place—oblivion—no matter how thickly the mathematical and algebraic dust may overlie and obscure the fundamental data assumed. It is to be regretted that Hoffmann spent so much time in the calculation of numerous tables for practical use (?). The time might have been so much better employed in some more useful direction.

2d. *Theories which assume the natural slope as the surface of rupture—friction being taken into account.*

In this last clause we recognize a real step in advance. The first assumption, however, invalidates the whole argument, and all such theories, wherever we find them, we can promptly discard.

Belidor (1729) was the founder of this school or method. He assumed that, without friction, the normal pressure upon the vertical wall would be equal to the weight of the prism formed by the natural slope. Friction he assumed to consume just half of this pressure. He took the point of application of the pressure at one-third the height of the wall. Assumption upon assumption, as we see, all without any warrant of fact. The only real advance consisted in the simple recognition of friction as an important element of the problem, not in the manner in which he took it into account. It seems strange that so many able men should give earnest attention to the subject and not recognize at a glance what every practical engineer would recognize by instinct, viz., that the amount of friction must determine how much of the earth will break loose, slide down, and force the wall. Yet upon a first hasty consideration it seems natural to admit that the amount pressing upon the wall must be the same as that which would slide down if the wall were not there. Hence the general assumption

at this period of the natural slope as the surface of rupture—an assumption which implicitly ignores entirely the influence of friction.

After Belidor we have Gadroy (1745), Trineaux (1768) and d'Anthony. The two last took the point of application of the thrust at two-thirds the height of the wall.

Gauthey gives a theory which coincides with that of Blaveau, only he deducts one-third from the parallel component by reason of friction.

3d. *Theories which assume a prism of greatest thrust and an earth pressure normal to the wall.*

The founder of this school is Coulomb (1773). We have all heard of him and his theory. He gave an impulse to the theory of the retaining wall characteristic of real genius, which it has never lost. He did not leave out of sight the physical data of the problem, but took them into account in framing his theory. In other words, he conformed theory to practice. Nine-tenths, I suppose, of the theories at present accepted and in use acknowledge him as their inspiration. It therefore becomes us to use him with respect. Nevertheless, his theory and those of his followers are defective. With Coulomb we reach a point where real progress begins, not merely in conception but also in execution—the peculiarities of the problem are not merely recognized, as indeed they were by some of the investigators already named, but they are to a large extent properly met, and not satisfied by rough assumptions which only recognize difficulties without meeting them.

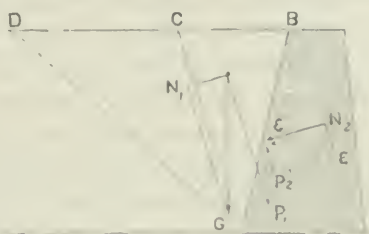
If we have shown anything thus far, we have shown that all preceding efforts from Vauban to Gauthey, were fruitless. So far as their labors are concerned they have been evil, and simply evil, because as we have seen in the case of Hoffmann and Maschek, their erroneous and totally valueless strivings are apt to turn up even in later times, with all the prestige of antiquity, to the confusion and botheration of the present generation.

With Coulomb begins a new era in the history of the subject. He did not reach the bottom, as has already been intimated, but he and his followers have moulded the formulæ which perhaps many engineers to-day use—if they ever use any—and he deserves, therefore, special mention. Let us try to make plain his method of dealing with the problem.

In the first place he took into account cohesion. This is a minor point and unessential to any theory, but yet necessary to be noted in

order to understand his method, therefore we notice it first. For it is evident that as cohesion helps the wall, a wall which is safe without it is so much the more safe with it. Its influence, moreover, is at best but slight, as every practical engineer knows, as the height at which earth will stand vertically without sliding is in general but slight.

According, then, to Coulomb's view, the surface of rupture is a plane, and along this plane surface a certain prism tends to slide. The pressure exerted by this prism upon the wall he *assumes* as normal to the wall. Here, then, we have at once the friction of the earth upon the wall disregarded. He decomposes the weight, G , of this prism and the reaction of the wall, E , into two components respectively par-



allel and perpendicular to the surface of rupture, and puts the difference of the parallel components, $P_1 - P_2$, equal to the resistance to sliding of the prism. This latter, however, consists of the friction, which is proportional to the normal pressure, N_1 , only, and of the cohesion which is proportional to the surface of sliding only. If we take the co-efficient of friction, equal to f , and the co-efficient of cohesion, *i. e.*, the cohesion for the area unity, equal to c , and the breadth of the prism, BC , for horizontal earth surface (this is the only case Coulomb discusses), equal to x , we have for the pressure upon the wall when vertical (this also is the only case discussed by Coulomb):

$$E = \frac{\gamma h x (h - f x) - 2 c (h^2 - x^2)}{2 (x - f h)}$$

where h is the height of wall, and γ the weight of a cubic unit of earth.

Now, as Winkler goes on to say, Coulomb concludes in a manner by no means clear, that, as the surface of rupture is assumed in different positions, the corresponding pressure upon the wall changes. For one position only is this pressure a maximum. The "prism of greatest thrust" must always tend to separate, because that resistance which

would keep in place this prism would so much the more keep in place any other. He therefore differentiates the above expression with respect to x , and putting the differential co-efficient equal to zero, finds for the value of x , which gives the greatest pressure,

$$x = -f h + h \sqrt{1+f^2}.$$

That is, *the position of the surface of rupture is entirely independent of the cohesion.* The corresponding greatest pressure is, of course, easily found. The point of application of this pressure, cohesion disregarded, is correctly shown to be at one-third the height of the wall.

Such was Coulomb's method. It was taken up and followed out in its consequences to all cases of walls inclined at any angle, earth surface at any angle, surcharged walls, etc., by Prouy (1802), Mayniel (1808), Français (1820), Navier (1826), Audoy and Poncelet (1840), Hagen (1853), Scheffler (1857), Saint-Guielhem (1858), Culmann (1866) and Mosely in recent times, as well as a host of others whom it would be useless to name, since the same assumptions lie at bottom, and they only differ in elaborateness of treatment and detail.

The objections which apply to Coulomb's method apply to all, as upon that they all stand or fall. The work of Poncelet was especially elaborate, and his graphic solutions, which enable the practical man to handle the rather involved algebraic expressions which abound in all the theories of this school, have done much to make his name in connection with retaining walls familiar to all. Yet it may be doubted whether the theory, even as popularized by him, has made much real headway, and whether engineers to-day bother themselves much with calculations and determinations of stability, in the case of a wall.

There is evidently a reason for this, as engineers to-day, though not apt to spend their time in mathematical recreations, are pretty quick to search out and make use of any real and efficient aid, whether from the side of pure or applied mathematics, or from that of successful practice or well-established usage. If the theory of Coulomb and his followers has not, then, found a lodgement in the practice of to-day, it is pretty good *prima facie* evidence that it does not meet the requirements of the case, and that when tried by the touchstone of practice it has been found wanting. However, we need not decide the merits of the case upon such showing. Objections more specific may be urged. All the authors we have mentioned thus far, from Coulomb down, assume a prism of maximum thrust. They all stand or fall with that.

Now, as Winkler points out, several objections may be urged against this.

In applying this principle, we decompose the weight, G , of any prism limited by a plain surface, AC , into two components, E and P_1 , acting upon the wall AB and the surface AC . Of these P_1 holds the friction and cohesion in AC in equilibrium. By this assumption E is determined for any *assumed* plane AC . E varies then with the assumed position of AC , and this position is so determined as to make E a maximum. Now here we have three objections.

1st. It is not apparent why the actual earth pressure should be exactly the maximum value of E for all positions of AC . No author, from Coulomb down, has given any direct satisfactory proof.

2d. The force P_1 , as the wall gives way, equilibrates only in the plane or surface of repose, AD_1 , while for every other plane P_1 is less than that necessary for equilibrium.

3d. E varies with the assumed position of AC , while nevertheless there can be really exerted upon the wall only one definite and constant pressure, entirely independent of the position of AC .

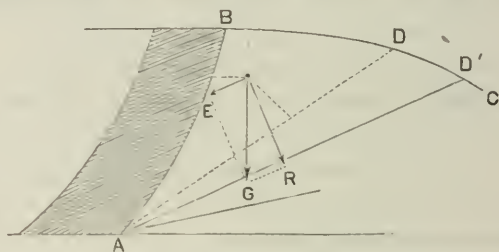
Any one of these objections invalidates Coulomb's theory, and leaves us still in the dark as to any satisfactory solution of the problem of the retaining wall. Engineering practice has, we think, thus decided, and the acceptable method has yet to be found.

There still remains a last method to be noticed, which is an improvement upon Coulomb's, and has proved the most generally acceptable of any. It is the theory of Rebhahn (1871), Winkler (1872), von Ott (1877), and is identical in its assumptions with the method followed by Ortman, Scheffler, Rankine, Levy, Considère and von Mohr, although these last proceed from a consideration of the conditions of equilibrium of the earth particles, and arrive at their results by integration. This we alluded to in the beginning as the second method of procedure, and as it is identical in its assumptions and results in the one we are about to describe, we may dispose of the two together.

Here, as in *all* the theories, we assume a plane surface of rupture. This is necessary in view of our necessary ignorance as to what this surface really is. Moreover, as experiment and observation show, this assumption is practically correct.

The wall AB may have any shape and inclination, as also the earth surface BC . Acting upon the wall is a certain pressure E , which is properly assumed as invariable in the reasoning, no matter where the

surface of rupture may be first assumed to lie. We thus avoid the objections to Coulomb's theory. Moreover, the pressure is not taken as normal to the wall, but as making a certain angle to the normal. Thus we take into account, very properly, the friction of the earth upon the wall when motion is just taking place. Now here I wish to direct careful attention—for it is a vital point. It is argued, and with some show of truth, that when motion is just about to commence by



reason of the yielding of the wall, or just upon the "verge of equilibrium," as it were, this angle of the earth pressure with the normal to the wall *must be just equal to the angle of repose of earth on wall*, or if this angle is greater than that of earth on earth, then to this latter angle, since, then, as the wall moves, a film of earth adheres to it, and a line of separation is between earth and earth. It is therefore on these grounds *assumed* that the pressure E makes an angle with the normal to the wall, at the verge of equilibrium, equal to the angle of repose of earth on wall or of earth on earth. These are the only two assumptions of this theory. The first, that of a plane surface of rupture, is necessary and common to all theories; we cannot afford to quarrel with that in our present state of knowledge. The second is that the earth pressure makes with the normal to the wall the angle of repose or of friction, where equilibrium just obtains.

If, then, we suppose a prism limited by any plane, AD , we have three forces, the weight of this prism G , the earth pressure E and the pressure R upon the surface AD .

As AD changes its position, *i. e.*, as we assume it to take different positions, E is properly considered as constant, since the imaginary section cannot affect the actual thrust on the wall (here was Coulomb's error) while G and R vary. For any one position of AD , then, G is determinate, and hence for constant E the intensity and direction of R for that position of AD is fixed by the parallelogram of forces, since

E , G and R must be in equilibrium. This pressure R , thus found, may be decomposed into a normal N to AD and a parallel force S . The normal force gives the friction of N along AD , when f is the co-efficient of friction. If the length of the surface AD is l and the co-efficient of cohesion is c , then the total resistance to motion along AD is $fN + cl$. The force S tends to cause motion along AD . Now, to have equilibrium we must have for any and every section AD , the condition

$$S \leq fN + cl.$$

For that section for which equilibrium just obtains and no more, we have

$$S = fN + cl \text{ or } \frac{fN + cl}{S} = 1.$$

This section is the surface of rupture. For all other sections

$$\begin{aligned} S &< fN + cl \\ \text{or } \frac{fN + cl}{S} &> 1. \end{aligned}$$

For the surface of rupture, then, the condition is that

$$\frac{fN + cl}{S} \text{ shall be a minimum.}$$

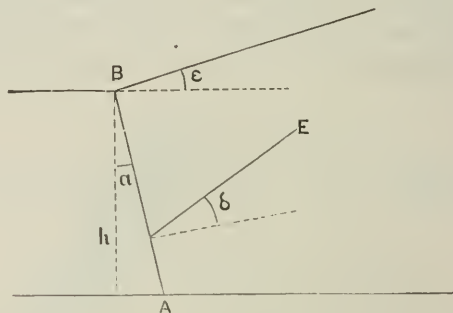
The surface of rupture is thus determined. G is then found, and then E .

This is, I think, a fair presentation of the last and best method which we shall notice—a method which to-day displaces Coulomb's, and which is to-day used in one shape or another by engineers, if they ever use any at all.

It rests, as we see, upon two assumptions, and only two. All objections must be made here or not at all, since the mere mathematical handling can be left out of sight. The first assumption, that of a plane surface of rupture, we must let pass, provisionally at least. It is fair to presume that its practical error is slight and more than balanced by neglecting cohesion, since the effect of this last is to help the wall. Let us direct our attention, therefore, to the second assumption, and see where it logically brings us out.

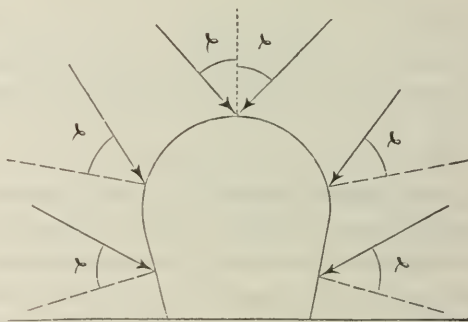
Prof. Weyrauch points out in the article referred to in the beginning of this paper the error of this assumption as follows. Let the angle made by the earth pressure E with the normal to the wall be δ , and

call the angle of repose φ . Coulomb and his followers for upwards of 60 years assumed $\delta = 0$, or, as we have seen, took the earth pressure normal to the wall. Since Poncelet (1840) it has been the prevalent fashion to assume $\delta = \varphi$, or equal to the angle of repose. The



reasons for such assumption we have just given. We have thus passed in the history of the subject from one extreme to the other. Is it not possible that the truth may lie in the middle? Let us see!

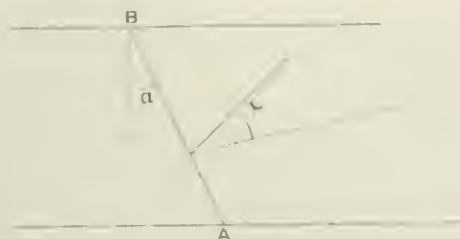
The assumption $\delta = 0$ was made because there then seemed no reason to suppose it anything else. No one ever attempted to prove it, but simply assumed that if the pressure was not normal the earth would slide. Many recent writers, however, contend that δ must equal φ , for at the verge of motion the earth is just on the point of sliding.



Let us admit their reasoning on this point, and apply the principle to a special case.

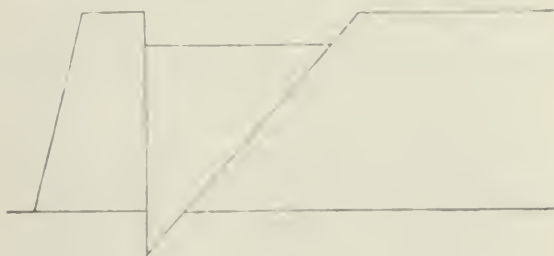
Consider an arch subjected to earth pressure. Then the earth pressure upon every element makes the angle φ with the normal at that point. Follow up towards the crown from either side, drawing

the earth pressure for different points, and we find at the crown two differently directed pressures at the same point, due to the same cause. Or, again; let us take a plane wall, AB . The earth pressure makes the angle φ with the normal to AB . Conceive the wall to turn about



A and take up different positions. For each new position the angle must be constantly equal to φ . Thus when the wall becomes horizontal the known *vertical* earth pressure must, according to our principle, still make the angle φ with the normal!

The principle is evidently not of general application, for it fails for horizontal position of the wall. Let the wall tip up again, at what position does the principle begin to hold good?



The assumption is evidently faulty. It does not represent facts, and the results of the theory built upon it cannot possibly, except by a balancing of errors not to be expected, be more correct than its data. Still the assumption *partially* represents fact. Thus to say that $\delta = \varphi$ is virtually to say that the wall slides out on its foundation only, and the prism sinks, as shown in the figure. For such a case the assumption would be correct. We must not, then, too hastily reject the theory *in toto*, but rather seek to estimate how and when to rely upon it, and when to reject it. This can be done only by comparison with the

results of a correct theory, which does not make use of this faulty assumption.

II. WEYRAUCH'S NEW THEORY.

Can such a theory be framed? Is there anything better to take the place of all these writers and investigators from Vauban and Coulomb to Poncelet, Mosely and Rankine? We would answer both questions affirmatively, and this constitutes the new theory to which, in view of the preceding history of the subject, we now wish in this paper to call special attention. The new theory was propounded by Prof. Weyrauch in the "*Zeitschrift für Baukunde*" for 1878 (Bd. I, Heft 2), and from the short historical review we have just taken, we are now in a position to estimate it at its true value, in so far as it claims to be an improvement upon all others, and only in so far as it does this, can it properly claim attention at all. Engineering literature, as we have seen, is too prolific upon this subject for any new theory to claim attention to-day unless its claims to such attention are well founded.

In the writer's opinion the new theory is in fact a real advance upon any hitherto advanced, and is free from the objections which apply to them. It is simple, and its results are practical. It enables us to properly estimate the value of the last method discussed, to show where it is at fault and when it is correct and why. We shall endeavor to present it briefly. For the details of the mathematical discussion the reader can refer to the original paper.* It will be sufficient for our purpose to examine closely its foundations, indicate the general method of discussion, and give its practical results in such shape that they may be used, tested and compared with those of other theories. Any one interested can then follow it out for himself, develop it further and add to its results. It remains, indeed, to be worked out into somewhat more practical shape for the working engineer, and to be applied to cases of surcharge, etc., but the foundations at least are laid, and seem firm.

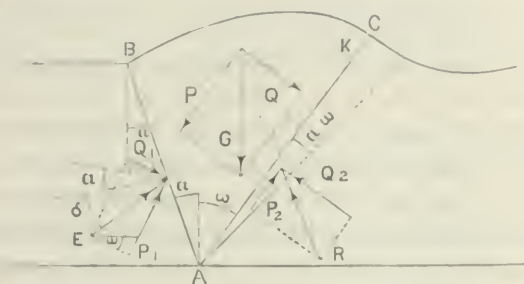
1st, then, we disregard cohesion, not that this is necessary to the theory, but simply that its disregard renders our results and algebraic work more simple and its introduction would not give any practical accuracy commensurate with the increased complexity of the resulting formulæ. Cohesion helps the wall a little. If we disregard it, a wall

* *Zeitschrift für Baukunde*, Bd. i, Heft 2, 1878.

which is safe by our method is simply still safer in reality. This assumption can then be granted us, for the sake of simplicity at least.

2d. We *assume*, and this is the *only* assumption we shall make, or which is necessary to be made, that the surface of rupture is practically a plane surface; that is, that all elementary forces acting upon any plane section through the earth, have the same direction or are parallel.

This single assumption of a plane surface of rupture is common to all theories. Without it we cannot start. We differ from all other theories in making no further assumption (that regarding cohesion is not essential). Let us now proceed to wind up and set in motion our mathematical machine. We give an outline of the manner in which this is done.



Let the surface of the earth have any form, and the wall AB any inclination. The earth pressure, E , makes some angle, δ , with the normal to the wall. What this angle is or should be we do not know as yet. We only say it must make *some* angle. We do not assume this angle to be the angle of friction. Conceive through the point A any plane section, as AC . The weight G of the prism ABC must be held in equilibrium by the pressure E , which this prism would cause on the wall, and the pressure R which it would cause upon AC . Wherever AC may be, if this prism ABC does not move, these are the forces which hold it in. We have then three forces in equilibrium. Let us decompose these three forces into components parallel and normal to AC . Then the necessary conditions for equilibrium are three, viz.:

The sum of the components parallel to AC must equal zero, or

$$P - P_1 - P_2 = 0 \quad (1)$$

The sum of the components perpendicular to AC must equal zero, or

$$Q - Q_1 - Q_2 = 0 \quad (2)$$

The sum of the moments of the forces E , G and R , about any point, must equal zero. Take the point of moments at A and let the lever arms be e , g and r respectively. Then

$$G g + E e - R r = 0 \quad (3)$$

Also, if φ is the angle of repose of earth on earth,

$$\frac{P_2}{Q_2} < \tan. \varphi \text{ or } \frac{P - P_1}{Q + Q_1} < \tan. \varphi \quad (4)$$

because if $\frac{P_2}{Q_2}$ were greater than $\tan. \varphi$ there could not be equilibrium.

This, therefore, is one of the necessary conditions of equilibrium.

Observe, $\frac{P_2}{Q_2}$ is not *assumed* equal to $\tan. \varphi$. It is simply asserted that it cannot be greater. It may be less and have any value below this limit.

Equation (3) is the condition which helps us through our solution and renders unnecessary any assumption as to the value of δ . Without it such an assumption is necessary. Here then is the point of divergence of the theory from all others. An arbitrary assumption is replaced by a sound principle, viz., that of equality of moments.

It seems strange that this third condition of equilibrium should never before have been introduced into the problem, and that therefore resort has been had to a questionable assumption instead. Yet such is the fact.

Our mathematical machine is now wound up. All we have to do is to set it in motion and let it grind out for us the inevitable consequences of these conditions of equilibrium. Human fallibility in calculation aside, he who looks for a flaw in the entire treatment must look for it in these first four conditions and the single assumption upon which they rest—that of a plane surface of separation.

If, now, there is anywhere in the mass of earth any one section as AC , for which

$$P - P_1 = (Q + Q_1) \tan. \varphi \quad (5)$$

then that plane is the true surface of rupture. The position of this plane is determined by the condition

$$\frac{P - P_1}{Q + Q_1} \text{ shall be a maximum.}$$

If this seems like the same reasoning which we discarded when

applied to the wall, a little consideration will show the difference. There it was *assumed* that at the verge of motion the earth pressure made an angle ζ with the normal to the wall. Here it is simply asserted that out of all conceivable sections AC , that one will be the real surface of rupture, for which the normal angle of R is the greatest consistent with equilibrium. This is undoubtedly true.

To find this position of AC we have to put, as we know, the first differential co-efficient equal to zero, or

$$\frac{d \left(\frac{P - P_1}{Q + Q_1} \right)}{d \omega} = 0 \quad (6)$$

From our figure we have for any position of AC ,

$$P = G \cos. \omega, \quad Q = G \sin. \omega, \quad P_1 = E \sin. (\omega + \alpha + \delta) \\ Q_1 = E \cos. (\omega + \alpha + \delta)$$

We have then from (5)

$$G \cos. \omega - E \sin. (\omega + \alpha + \delta) = [G \sin. \omega + E \cos. (\omega + \alpha + \delta)] \tan. \zeta.$$

Since this equation holds good only for the surface of rupture, we have for the earth pressure upon the wall AB , when ω is the angle made by the surface of rupture with the vertical,

$$E = \frac{\cos. \omega - \sin \omega \tan. \zeta}{\sin. (\omega + \alpha + \delta) + \cos. (\omega + \alpha + \delta)} G = \\ \frac{\cos (\zeta + \omega)}{\sin. (\zeta + \omega + \delta)} G \quad (7)$$

We have then from (6)

$$\frac{d}{d \omega} \left(\frac{G \cos. \omega - E \sin. (\omega + \alpha + \delta)}{G \sin. \omega + E \cos. (\omega + \alpha + \delta)} \right) = 0$$

If, now, we represent the length of AC by γ , and let γ be the weight of a cubic unit of earth, then

$$d G = \frac{1}{2} k d \omega + k \gamma$$

and by performing the differentiation we obtain

$$\frac{G}{E} - 2 \sin. (\alpha + \delta) - \frac{k^2 \gamma}{2 G} + \frac{E}{G} = 0 \quad (8)$$

Substituting the value of $\frac{G}{E}$ from (7) we have for the weight of the prism of rupture

$$G = \frac{\cos. (\varphi + \omega) \sin. (\varphi + \omega + \alpha + \delta)}{\cos. (\alpha + \delta)} \cdot \frac{k^2 \gamma}{2} \quad (9)$$

Substituting the value of $\sin. (\varphi + \omega + \alpha + \delta)$ found from this equation in (7) we have for the earth pressure on the wall

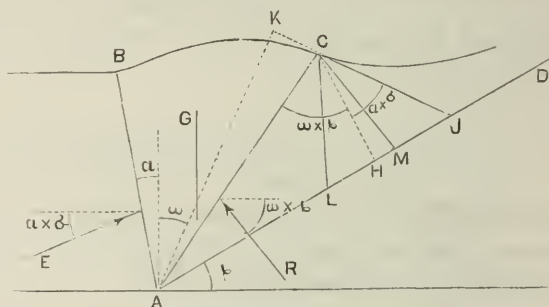
$$E = \frac{\cos.^2 (\varphi + \omega)}{(\cos. \alpha + \delta)} \cdot \frac{k^2 \gamma}{2} \quad (10)$$

and since the sum of the horizontal components of E , G and R must be zero

$$E \cos. (\alpha + \delta) = R \cos. (\omega + \varphi)$$

hence

$$R = \cos. (\varphi + \omega) \frac{k^2 \gamma}{2} \quad (11)$$



It is now easy to prove the following relations: If AD is the natural slope, and we draw from the end C of the surface of rupture a line CI , making the angle $\alpha + \delta$ (or the angle of E with the horizontal) with the normal to AD , then the area of the triangle ACI is equal to the area ABC of the prism of rupture. If we lay off IL equal to IC , then γ multiplied by the area CIL gives the thrust E . If we lay off AM equal to AC , then γ multiplied by the area of ACM gives the pressure R upon the surface of rupture, all for one foot in length of the wall. That is area, $ABC = \triangle ACI$, or

$$G = \gamma \triangle ACI$$

$$E = \gamma \triangle LCI$$

$$R = \gamma \triangle ACM$$

where the symbol $\triangle$ denotes "area of triangle." The first two of these relations were deduced by Rebhahn in 1871, under the assumption that $\delta = 0$ or $\delta = \varphi$. They are here found to be true independently of any such assumption. The third relation is new and is due to our third condition of equilibrium. We have thus the relation

$$G : E : R = AI : IC : AC \quad (12)$$

or the weight of the prism of rupture and the pressures upon the wall and surface of rupture are as the three sides of the triangle ACL .

We have made no assumption as to the value of δ . The value of this angle is given at once by equation (3), for any particular case. This equation, therefore, which is one of the necessary conditions of equilibrium, answers the same end as the unwarrantable assumption of $\delta = 0$ or $\delta = \varphi$.

So much for the general case. For any special case we can now easily find G , E and R and the values of ω and δ . Let us suppose, for instance, that the earth surface is plane and slopes up at any angle ε . For this case it is easily proved that if BO is drawn, making an angle with the normal to the natural slope equal to $\alpha + \delta$, then AI is a mean proportional between AO and AD . We can, therefore, easily construct AC , provided δ is known.



The special value for K_2 in this case, becomes

$$F_2 = \left[\frac{\cos(\varphi - \alpha)}{\cos \alpha} \right] \frac{h^* \gamma}{2 \cos(\alpha - \beta)} \quad (13)$$

We have also two equations containing ω and δ , by means of which each can be determined. The first is easily found from the figure to be

$$\frac{\sin(\alpha + \omega) \cos(\xi + \omega) \cos(\alpha - \eta)}{\cos(\zeta + \omega) \cos(\alpha - \xi)} = \sin(\zeta + \omega + \alpha - \eta) \quad (14)$$

The second is found to be

$$\begin{aligned} & \cos. (\varepsilon + w) [\cos. (\zeta - w) \cos. \delta - \sin. (\zeta + w - \alpha + \delta) \sin. \alpha] \\ &= \cos. (\alpha - \varepsilon) [\cos. (\alpha - \delta) \cos. \zeta - \sin. (\zeta - w - \alpha + \delta) \sin. w] \quad (15) \end{aligned}$$

The point of application of the earth pressure is easily proved to be *at one-third the height of the wall from the bottom.*

We have not thought it necessary to give the details of the mathematical work by which these results are obtained. Our object is simply to point out in outline the method of discussion and to give briefly the practical results.

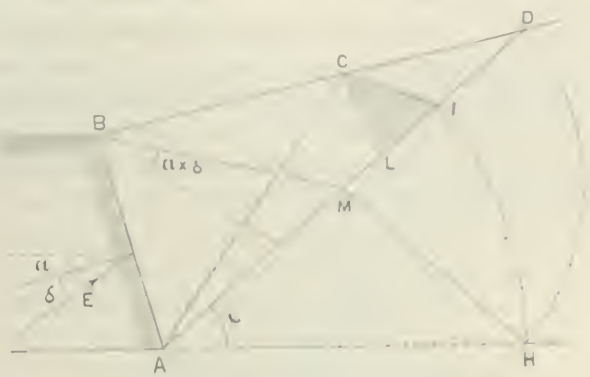
Equations (13), (14) and (15) include, then, every practical case that can ever occur, of wall inclined at any angle and earth sloping at any angle. They even include the special case of water pressure, for which ε , φ and $\delta = 0$ and $\omega = 90^\circ$. The theory is, as we have seen, free from objections which may be urged against all others, and is thus the best that has been framed. These three formulæ will enable any practical case to be easily solved, and though long they are sufficiently simple. In any special case, numerical data being given, they become quite short and easily worked. Of themselves, therefore, they constitute all that is needed, but of course in particular and special cases they admit of simplification, and for each special case we may deduce a construction founded upon the formulæ which will enable the desired results to be obtained graphically without any calculation at all.

We shall therefore give the equations, deduced from these general ones, which solve the more important special cases occurring in practice, and also the graphic constructions by which the same results may be obtained without calculation. Any one noting these down will have at disposal the results of the method upon a single page of his notebook, and can compare results with those of other theories.

I. GENERAL CASE. EARTH AND WALL AT ANY ANGLES.

For this case we have the general equations (13), (14) and (15), just given. In any given example we can find δ by equations (14) and (15), by finding ω in terms of δ from one, and inserting in the other. Having thus found δ , equation (13) will give us E , or the earth thrust, which is to be considered as acting at one-third the height of the wall from the bottom. We may also find E by construction. Thus, draw from the top of wall BM , making the angle $\alpha + \delta$ with the normal to the line of natural slope AD . Upon AD describe a semicircle, and draw MH perpendicular to AD . Make $AI = AH$. Then AI is a mean proportional between AM and AD . Draw IC parallel to BM and produce to intersection C with earth surface BD . Then AC is the surface of rupture. Make $IL = IC$. Then $\angle ICL$ gives E . The direction of E is given by the angle $\alpha + \delta$. Its point of application is as given above. We can now find the moment of this thrust

with reference to the outer edge of wall and then determine what thickness the wall should have in order that its weight may more than counterbalance this moment by as great an excess as may be desired.



II. EARTH SURFACE HORIZONTAL.

Here ε becomes zero in (13), (11) and (15), and we have, after suitable reductions,

$$\left\{ \begin{array}{l} E = \tan.^2 \left(45 - \frac{\varphi}{2} \right) \frac{h^2 \gamma}{2 \cos. (\alpha - \delta)} \\ \text{or} \\ E = \frac{\tan. \alpha}{\sin. (\alpha + \delta)} \frac{h^2 \gamma}{2} \end{array} \right. \quad (16)$$

which latter will apply for any value of α not equal to zero, or when wall is not vertical.

$$\text{We have also} \quad \omega = 45 - \frac{\varphi}{2} \quad (17)$$

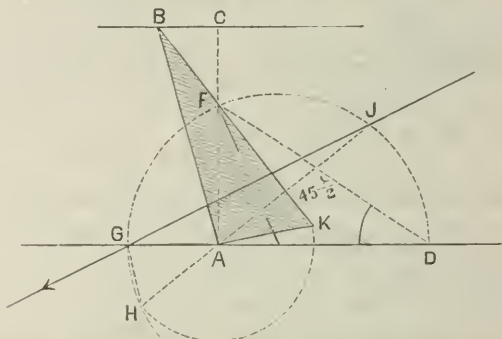
and

$$\left\{ \begin{array}{l} \tan. \delta = \frac{\sin. \varphi \sin. 2 \alpha}{1 - \sin. \varphi \cos. 2 \alpha} \\ \text{or} \\ \tan. (\alpha + \delta) = \frac{\tan. \alpha}{\tan.^2 \left(45 - \frac{\varphi}{2} \right)} \end{array} \right. \quad (18)$$

the latter equation being in general most convenient to use.

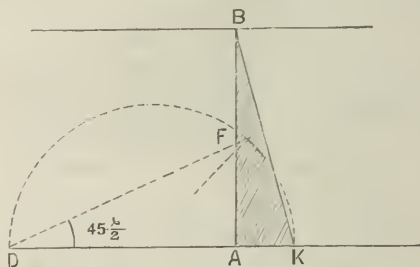
These equations are quite simple, and easily solve any case under this head.

It may also be easily proved by a discussion of the value for δ , that $\delta = 0$ only when the wall is vertical or horizontal, as evidently should be the case, while for $\delta = \varphi$, the wall must make the same angle on one side of the vertical that the surface of rupture does on the other, or $\alpha = \omega$. For any other inclination of the wall δ is intermediate between 0 and φ , as given by equation (18). We see thus, that here the truth does lie in the middle between extremes, and that for horizontal earth surface, the assumptions $\delta = 0$ and $\delta = \varphi$ give correct results only for two definite inclinations of the wall, and results more or less incorrect for all others.



Instead of using the formulæ we may construct the earth pressure here, entirely without calculation, as follows :

Make $AD = AC$, and the angle $ADF = 45^\circ - \frac{\varphi}{2}$. Construct a circle through F and D with its centre in AD : Draw GH parallel to AB . Produce HA to intersection I . Then IG gives the direction of



the earth pressure. Draw AK perpendicular to AB and make it equal to AH . Then $\triangle ABK$ gives the thrust per unit of length of wall.

If the wall is vertical the construction is simplified—thus:

Make $AD = AB$, and angle $ADF = 45^\circ - \frac{\varphi}{2}$. Construct circle through F and D with centre in AD . Then γAKB gives thrust, which of course is perpendicular to wall.

III. THE EARTH SURFACE HAS THE NATURAL SLOPE.

For this case we have

$$\omega = 90 - \varphi \quad (19)$$

$$\tan. \delta = \frac{\sin. \varphi \cos. (\varphi - 2a)}{1 - \sin. \varphi \sin. (\varphi - 2a)} \quad (20)$$

or

$$\tan. (a + \delta) = \frac{\sin. a + \sin. \varphi \cos. (\varphi - a)}{\cos. \varphi \cos. (\varphi - a)} \quad (21)$$

$$E = \left[\frac{\cos. (\varphi - a)}{\cos. a} \right]^2 \frac{h^2 \gamma}{2 \cos. (a - \delta)} \quad (21)$$

We find that in this case, therefore, the assumption $\delta = 0$, is correct only when the wall makes the angle $a = 45^\circ - \frac{\varphi}{2}$ with the vertical, and that $\delta = \varphi$ when the wall is vertical only. For all other inclinations of the wall δ is intermediate between 0 and φ , and all other theories which give δ an invariable value are necessarily incorrect.



Instead of the above formulæ, which are, however, sufficiently simple, we may solve the present case also by construction alone.

Thus draw GA parallel to the earth surface. With the vertical AC as radius describe a semicircle ADG . Draw DF horizontal and GH parallel to AB and then produce HF to intersection J . JG is the direction of the earth pressure. Make AK perpendicular to AB and equal to HF . Then $\gamma JABK = E$.

We can thus solve graphically those cases which occur most frequently in practice, while the formulæ themselves are by no means complex. In all cases the point of application is to be taken at one-third the height of wall from the bottom. The direction and intensity of E being then known, we can, for any case, easily find the thickness of the wall, which will give the moment of stability any desired number of times greater than the moment of rotation.

THE RELIABILITY OF THE NEW THEORY.

And now, in conclusion, a few words as to the reliability of this new theory. Here we may let Prof. Weyrauch speak for himself: "It is, as we have seen, based only upon the single assumption of a plane surface of rupture. If it can be proved that this assumption is correct, then our theory is exact. A conclusion as to this point can only be reached by investigating the conditions of equilibrium of the earth elements. This is the method of Rankine, Winkler, Levy, Considère and Mohr, already referred to. Now this method proves that for an unlimited earth mass, without cohesion and with earth inclined at any angle, the above assumption is correct. The question, then, reduces to whether the same holds good also for an earth mass when limited by a wall. In any case, we can say that our theory is exact, if Rankine's theory of earth pressure in a mass of earth without cohesion and limited by a wall is correct." Both theories conduct to the same results, apart from the δ assumption. However this may be, it can be proved that the theory is correct at least for horizontal earth surface and a wall not inclined backwards, *i. e.*, for $\alpha \geq 0$. We arrive, therefore, at the conclusion, that for case II, the formulæ and constructions given for horizontal earth surface and wall not inclined back of vertical, *are mathematically exact and give perfectly accurate results.*" So much, then, at least, is clear gain, and as this case includes many, if not most practical cases, it is well to call attention to the accuracy of our method here.

If the wall inclines back, or α is negative, then, without doubt,

neither the new theory nor any other holds completely. The surface of rupture is then no longer a plane, and the earth pressure is still an unsolved problem. In all practical cases the difference is but slight, and our theory commends itself as the one involving the fewest assumptions. So much, at least, we know, that the earth pressure must be zero when the backward angle of earth with wall $\alpha = -(90 - \varphi)$, because then the earth has the natural slope, and would stand, even without a wall.

To recapitulate, then :

For wall vertical or slanted forward we may use the results of I, II or III with confidence.

For wall slanted back, we must proceed still according as experience or custom may suggest or sanction.

The results hitherto given by older methods may be found from the new, by putting $\delta = \varphi$ or $\delta = 0$.

Such is, in brief, the new theory of the retaining wall to which we wish to direct attention. We have, of course, spoken from a purely mathematical standpoint. We by no means leave out of sight the fact that there are destructive agencies, such as water, frost and decay, which can never be drilled into any formula, and which can never be safely disregarded by any engineer. We do not forget that the earth mass is not always homogeneous, and that the "angle of repose" is a very variable quantity. We might go on to enumerate other disturbing conditions which no mathematics can grapple with, but it is scarcely necessary. The intelligent engineer, who understands how his formulæ are obtained, understands equally what they do not and cannot cover as well as what they do, and recognizes those conditions which experience only can meet. The only questions which arise are, whether he is better off with experience alone, or with experience *plus* theory? If the latter, should not the theory be as free from unnecessary assumptions as possible?

Suspension and Elevation of Clouds.—M. Oltramare supposes that the altitude of clouds is determined by the force of electrical repulsion between the clouds and the stratum of air below them. If the electricity is uniformly distributed, in accordance with any simple function of the height, the hollow sphere of air above the cloud can exert no influence.—*Comptes Rendus*. C.

A SYSTEM OF ELECTRICAL STORAGE.

By Profs. EDWIN J. HOUSTON and ELIHU THOMSON.

The various suggestions which have hitherto been made for the storage of electrical energy, in such manner as to readily permit its after recovery in the form of electrical current, have failed when attempted to be carried into practice, either on account of their inherent impracticability, or by reason of the serious inconveniences and losses due chiefly to the following:

1st. The extent of conducting surface of the storage apparatus required to be acted on, rendering it cumbrous.

2d. The loss of energy due to evolution of gas during the operation of charging.

3d. Lack of constancy and duration in the currents evolved after charging.

4th. The limited capacity for storage due to the proportion of active material being but a fraction of that present.

The well-known Planté Secondary battery is open to all of the above inconveniences, and though admirable in its conception as a piece of scientific apparatus, yet lacks markedly the requisites of an economical reservoir for electrical action. In the secondary battery, as is well known, the duration of action is chiefly dependent upon the amount of surface of the lead plates employed; the action of the current used to charge it being practically limited to the surfaces of the plates, and the charge received may therefore be designated as due chiefly to polarization. Moreover, the charge received is necessarily limited on account of the evolution of gas.

It is manifest that a Smee cell, or cell with vertical plates, in an acid solution, could not be used in the process, for the only effect would be the evolution of the gases hydrogen and oxygen from the decomposition of water.

In the system of electrical storage devised by us, the duration of action and consequent capacity for storage is independent of extent of surface and dependent on the mass of material to be acted upon.

In our method we employ a saturated solution of zinc sulphate, enclosed in a suitable vessel, at the bottom of which is placed a plate

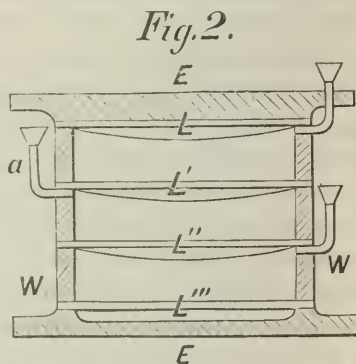
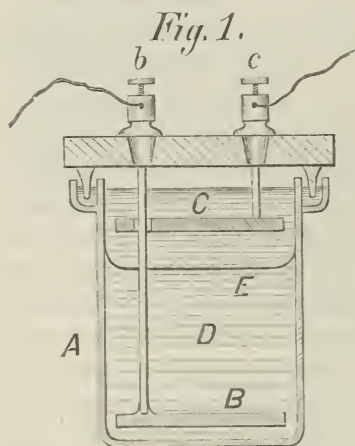
of copper, to which is connected an insulated conducting wire. At or near the top of the vessel, and immersed in the solution contained therein, is placed a second copper plate, or plate of hard carbon, or metal unchanged by contact with zinc sulphate solution, and less positive than metallic zinc. This is also connected to a wire. The storage cell so constituted is then ready for charging, which is effected by the passage through the cell of a current, whose direction is from the lower to the upper plate. The current employed is that obtained from a dynamo-electric machine, and the result produced is the deposition of metallic zinc on the upper plate, and the formation of a dense solution of copper sulphate overlying the under plate. The duration of the charging action is of course limited only by the amount of zinc sulphate and the thickness of the lower plate. The cell, after charging, constitutes in fact a gravity cell, and continues a source of electrical current until a reconversion of all the copper sulphate into zinc sulphate has been effected, metallic copper being deposited on the lower plate, and the deposit of metallic zinc being removed from the upper. It thus may be allowed to regain its original condition. The recharging, however, may be effected at any time, either before or after the cell has become inactive. The cell may be covered or sealed to prevent evaporation; and since no addition of new material is needed, a restoration to an active condition is at any time possible.

It is not necessary to employ zinc sulphate as the material to be decomposed, since other metallic salts may serve the same end, the only other requisite being that the lower plate shall yield to the solution a metal capable of redeposition, and the solution of which is denser than the solution employed in the cell, and that the upper plate be capable of receiving a metallic deposit and of retaining its form unchanged during prolonged use.

A, Fig. 1, represents a cell of glass, or other suitable material, furnished with two metallic plates, *B* and *C*, connected separately by conducting wires to the binding posts, *b* and *c*, the wire from the lower plate being insulated. A porous diaphragm, *D*, is placed below the upper plate, *C*, to prevent fragments of deposited zinc from falling on the lower plate, which may occur should the charging current be too intense.

In charging, the arrangement of the cells in multiple arc or in series may be adapted to suit the electro-motive force of the dynamo-electric machine employed. The arrangement of the cells in charging may

be different from that in discharging, according to the purpose for which the current is designed. Diffusive action of the solutions may be prevented by any of the well-known means used in gravity cells.



It may be objected that the economical results obtained in the storage of electricity as above described will necessarily be low, as but a fraction of the electrical energy in charging will be expended in overcoming counter electro-motive force, or in effecting electrolysis, compared with that which overcomes the resistance of the liquid, and therefore lost in heat production. But this objection is readily met by so connecting the cells as to make their counter action or counter electro-motive force the chief resistance to its passage. Economical results necessarily follow, the economy attained being measured by the relative cost of the fuel required to drive the dynamo-electric machine and that of the zinc and chemicals used for charging a battery of equal power to that of the storage battery used.

The resistance of the liquid between the plates of a storage cell may be lowered either by broadening the cell or by bringing the plates nearer together. In charging, economical results are obtained by using the plates comparatively near to each other, and separating them during discharge, and thereby avoiding loss by diffusion.

A convenient form of storage battery, designed for rapid charging and discharging, is shown in Fig. 2, where L , L' , L'' , L''' are horizontal plates of copper separated by insulating rings, W , W , the spaces between the plates, L , L' , etc., being filled with a saturated solution of

zinc sulphate. Lateral tubes, *a*, are provided to compensate for the expansion of the liquid due to changes of temperature, and also to provide for filling the cells. The cells are held between plates *E E* by bolts which pass from one to the other. In this arrangement, the plates *L'* and *L''* serve as upper and lower plates, accumulating copper sulphate on their upper surfaces and receiving metallic zinc on their under surfaces. The series may of course be extended.

When a number of cells are connected in series, several of them may be charging, while the remainder are used as a source of active current.

The most obvious application of a storage battery furnishing a constant and lasting current, is to replace the ordinary telegraphic batteries; the objections to the direct use of the dynamo-electric machine being mainly the necessity for continually sustaining the driving power and preventing variations or intermissions therein; to adapt the current generated to the work to be done; and to sustain a uniform electro-motive force in said current. By the use of a storage battery, the dynamo-electric machine may be run at suitable intervals to produce and sustain the charge of said battery. The economy and convenience of this arrangement will, we believe, be vastly greater than with the ordinary batteries in use.

In lighthouses, a dynamo-electric machine can be run by suitable power at intervals during the day to furnish an unfailing and reliable source of current for lighting purposes.

The purposes for which the storage batteries may be applied are so numerous that mention need not be made of them, the feasibility of each being decided by the question of its economy.

In domestic economy it would be feasible to provide storage batteries to be charged by dynamo-electric machines from convenient central locations, the energy of said batteries to be used in the operation of burglar and fire alarm systems, or for light driving power.

It is practicable in good forms of dynamo-electric machines to realize in external work from 50 to 60 per cent. of the power used in driving them. Of this we believe it possible to store and recover 50 per cent., or even more. Therefore 25 per cent. of the original power may be given out secondarily as electrical current. If it be assumed that in the best steam engines it is possible that 20 per cent. of the heat energy of the coal be utilized, then about 5 per cent. of the heat energy might, we think, be recovered after storage as electrical current.

Notwithstanding this small percentage, the economy would be much superior to the employment of zinc and other materials used in the ordinary battery in the production of current.

CENTRAL HIGH SCHOOL,

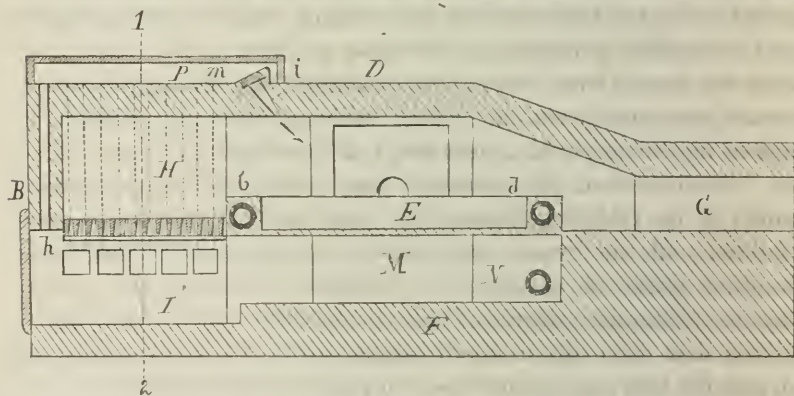
Philadelphia, November 22d, 1879.

IMPROVED PUDDLING AND HEATING FURNACE.

By JAWOOD LUKENS.

Read before the Franklin Institute at its meeting Oct. 15th, 1879.

The working of the furnace is as follows: The blast from a fan or blower enters the ash-pit, either in the ordinary way, by a pipe at one side, or, preferably, is blown into the air-chamber, *M*, under the bottom plates, and, passing along through the chamber, becomes heated considerably, and at the same time cools the bottom plates somewhat, thus protecting the working bottom of the furnace. The blast may be passed through the chills of the furnace before entering the air-chamber, *M*, and thereby become heated; this, however, is not necessary to the successful working of the furnace. Of the blast entering



the ash-pit a portion is carried up through the grate bars and fire to support combustion in the fire-chamber; while another portion passes, by means of the vertical pipes or passages in the walls, to the air-chamber, *P*, on top of the furnace. In passing from the ash-pit to the air-chamber on top, the air becomes highly heated and at the same

time serves to cool the walls of the fire-chamber, thus protecting the brick-work by keeping the temperature below what it otherwise would be. The air while in the air-chamber on top becomes still further heated by taking up heat from the bricks of the roof, thus keeping them cooler than they otherwise would be. From the air-chamber on top, the air, highly heated, is driven through the inclined tuyeres or openings in the roof, into the working chamber, producing rapid combustion of the gases and smoke passing over the bridge wall from the fire-chamber, and intense heat just at the point where it is needed, and at the same time deflecting the flame towards the bottom of the working chamber, and the metal to be operated upon. This depression of the flame tends also to save the brick-work over the working chamber. The combustion in the fire-chamber being less than in an ordinary furnace, the heat there also is less, which lessens the formation of clinkers and destruction of the brick-work. The force of the blast passing through the coals being less, the flame does not strike the roof with the same force as ordinarily, and consequently the wear of the bricks is not so great on this account. The actual result of this saving of brick-work has been found to be great, the brick-work of the fire-chamber lasting much longer than formerly. By means of the valve in the tuyeres the amount of the top or secondary blast can be regulated and proportioned to that passing through the grate bars exactly as required. The top blast entering the working chamber, *always* highly heated, immediate combustion of the gases and free carbon takes place, and no loss results from free oxygen reaching the metal on the hearth, as would otherwise be the case. An oxidizing flame can, however, be produced by working with a clear fire, and thus having an excess of air enter. By reason of the increased heat produced in the working chamber of the puddling furnace, the time required for the operation is reduced and the furnace can always be worked very "close," thus preventing waste of metal from oxidation. Having the furnace always at the required degree of heat, the metal is drawn out in better condition than from the ordinary furnace, which frequently works too cold, and the ball consequently goes to pieces in the squeezer.

In placing this improved puddling and heating furnace among the valuable improvements in iron manufacture, the claim is not made for economy of fuel only, nor is any claim made for its being the most economical in this respect. But the combined advantages over

the ordinary forms of such furnaces are deemed worthy of consideration. The great bulk of iron puddled and reheated is worked in the ordinary furnaces, either with draft or blast, with a reckless waste of fuel; and although there are many kinds of improved furnaces, claiming to do the work on miraculously small quantities of fuel, not one of them has been generally brought into use; either on account of expensive alterations and necessary changes of the arrangements of mills already built, or difficulty of manipulation and expense and annoyance of instructing workmen properly to use them, or for some other reasons. This furnace, while being sufficiently economical, compared with the ordinary furnace, to make a great saving in the cost of manufacture, has none of these disadvantages. The cost of construction, or changing from the old furnace to this, is so small as to be unimportant. There is no risk of trouble or annoyance in making the change, as the furnace could be used in the ordinary way simply by shutting the top blast damper. It requires no resetting of furnace plates or change of foundations; no alteration of the size or shape of the old furnace, but merely rebuilding of the fire-chamber, with the addition of the few pounds of iron work required in the construction. The advantages of the furnace are many, viz.: A saving of fuel, of from 25 to 40 per cent. A saving of ore "fix" of from 5 to 10 per cent. A less waste of metal in puddling of about 2 per cent. A much longer run of the furnace without repairs. A saving of labor required in working the furnace. Shortening of the time required for the operations going on in the furnace. Better condition of the iron when drawn from the furnace. Obviating, in heating furnaces, the evil of "blowing over" coal dust, and obtaining a clean, soft heat for pile or billet, and thereby to a great extent avoiding defects in the plate or shape to be rolled. The working of the furnace requires no special instruction or training of the workmen, any ordinary puddler or heater being able to work the furnace successfully.

The result of more than a year's use of these furnaces has demonstrated all of the foregoing assertions to be facts, and has shown that with them, as compared with the ordinary forms, more and better iron can be produced with less fuel, less "fix," less cost of brick-work and less labor in about the proportions set forth above.

STEAM BOILER EXPLOSIONS.

By E. A. CORBIN and H. G. GOODRICH,

Agents of the Hartford Steam Boiler Inspection and Insurance Company.

In the JOURNAL OF THE FRANKLIN INSTITUTE for October last appears an article on "Steam Boiler Explosions," referring to the late disaster at the Messrs. Wilt & Sons, which we desire particularly to notice, because it contains several erroneous statements of fact as to the exploded boiler, and which, as written and illustrated, will certainly mislead readers as to the particulars of the boilers of Mr. Campbell, referred to in said article.

The writer of this article says there were "three necks" to the Wilt boiler, that these necks leaked, that they were the weakest parts of the boiler, and that the boiler burst at the necks. The facts are, the boiler had *four* necks, the exploded boiler showed no sign of incipient rupture at the necks, and no such cracks in the sheets, or sheared or broken rivets at these seams; there were no known leaks at the necks, and no evidence of any on the sheets to which the necks were secured. Three of the necks remained intact, fast to the upper boiler; one of them was torn open by the separation of the two boilers during the progress of the explosion, while all of them were torn in the solid part at and above the angles at the lower boiler, and at no place on any of the necks were the seams parted, neither those seams which held the necks to the lower boiler, nor their longitudinal seams. They were all single riveted.

The leak referred to in the direct testimony was at the tube ends, and from a break in the rear tube sheet, in a line between the centres of two adjacent tubes; the fractured part, which had been mended by a lap strip bolted on, passed through the explosion without being disturbed.

The writer continues: "The two new boilers made for Wilt & Son are constructed upon nearly the same principle as that of the exploded one."

It is proper, we think, to qualify this word *nearly*. The exploded boiler consisted of a horizontal tubular boiler filled with tubes, connected at its top to a similar horizontal boiler, without tubes, by four

wrought iron necks; atop of this was connected a horizontal steam drum by two wrought iron necks. The water was carried near six inches above the middle of the second boiler.

The new boilers consist each of one horizontal boiler with tubes in its lower half, having the water carried a few inches over the top row of tubes, leaving nearly half of the boiler for disengagement and distribution of steam; over this boiler is mounted a horizontal steam drum, connected by two wrought iron necks.

The former is the type known as the "double-decker;" the latter is the plain horizontal tubular type, each provided with a steam drum.

Referring again to the explosion, we are fully assured by the results of the disaster that the rupture was mainly through solid iron, and independent of the known weaker lines along the rivet holes of the seams of the necks, showing conclusively that no initial rupture at the necks, such as stated by the writer of the article, occurred. The initial rupture, so far as known, was along the longitudinal seam at the side of the tubular boiler, where the old and new plate joined, and from thence went tearing through the strongest portions of the sheets, utterly regardless of seams, necks or anything else, and there was no line of fracture that in the least degree gives any ground for the theory that the necks were the weakest parts, certainly not to the forces in action during the explosion.

In all, there were sixty-three lineal feet of torn sheets, of which only two feet were along the longitudinal seam at the side of the tubular boiler. It is to this seam that all the evidence points as the place where the explosion began, the very place of all others in the boiler where the strains caused by contraction and expansion of the sheets, by the greater heat imparted to the lower half of the boiler, would act in the severest manner.

Nine years of constant use for a boiler of well-known qualities for rapid generation of steam, fired with shavings in the usual way by an engineer of known carefulness and efficiency, in the employ and under the constant supervision of the Messrs. Wilts, who never left any duty undone, nor spared expense, nor ran any risk, if the least sign of danger appeared, but ordered repairs done at once, and whose motto was "safety at whatever cost"—even such treatment, in the best wisdom of man, might wear out any iron structure. Nevertheless this is true; when in the full tide of business, with every appliance in the best of repair and in successful operation, as reported by the engineer the evening

previous to the explosion, who said to Mr. Wilt, "Every thing is in tip-top order," who will tell when and where rupture will begin?

Moreover, this boiler was carefully and thoroughly inspected by us a short time previous to the explosion, when no visible sign of weakness manifested itself. There was little or no wasting away of the sheets by corrosion, very slight scale in the boiler, not a defective rivet, nor a crack to be seen. There was not the first evidence of defect, decay or weakening visible, nor any change as regards safety from what was fully known of the boiler during all the past nine years of its use while under our care and inspection.

In addition to this testimony, we have the statement of the City's Chief Inspector to the effect, and with full knowledge of all the details of the exploded boiler, that had he with present knowledge made personal examination of this boiler the day before the explosion he could not have found defect anywhere, and would have passed the boiler as safe under 80 lbs. of steam, the same as we had done, declaring, also, that the repairs were properly made, that no weakening could possibly result from the blisters in the sheets (as proven by all of them going through the explosion without change), that no defective rivets were to be seen, that there was no visible deterioration of the sheets, that no damaging scale was anywhere to be found, and that no question was raised about the manner of securing the tube ends.

The testimony of the explosion silenced all speculations about the tubes, by demonstrating conclusively that the shell burst asunder before they gave way; that is to say, the boiler was exploded while the tubes held on, but they finally yielded to increasing pressure when the shell was torn.

Since the explosion, specimen pieces, cut with and across the grain, have been taken from each and every sheet for testing. The result given by competent men who experimented in all fairness, considering the elasticity as well as the tensile strength, proves that "no fault can be found with the iron" in this boiler.

A writer in *JOUR. OF FRANK. INST.* for August last says:

"The proportion and operation of the two safety valves were all that could be wished. The competency and carefulness of the engineer was maintained by all witnesses. No blame could be attached to any one, with any fairness, for the occurrence of this disaster."

With those who have studied the details of this explosion carefully, seeking for the truth alone, there can be but one true verdict, and that

is, that the makers of the iron, and the makers, users and inspectors of this boiler have done their best throughout. More than this men cannot do.

The "Report on the Explosions of Steam Boilers," in JOURNAL OF FRANK. INST., Dec., 1836, p. 364, says: "There can be no doubt that the strength of boilers may be diminished by constant and often unequal pressure, by which the material is injured so far as to give way under a less strain than that which it may once have borne." Further on in this most interesting and thorough "Report on Strength of Materials for Steam Boilers," August, 1837, p. 103, we find the following words, under the head of "Effects of Use and Long Exposure on the Strength of Boiler Iron": "This topic may be regarded as one of the most important which came under the notice of the Committee."

It is subject of regret that more was not done by the jury to ascertain beyond doubt the effects of long use of the iron in question; more especially interesting in this case, as the wasting of the iron by corrosion was very little, as was also the visible weakening of the joints and plates, which would at once suggest the probability of molecular change in the iron under heat and strain, an infirmity to which all iron under repeated strains is liable, and which even now is among the less known phenomena of metals.

The tensile strength per square inch of the test pieces cut from the used boiler plate reported by the Franklin Institute Committee, referred to above, show figures ranging from 46,000 to 54,000 lbs., which are singularly near to those of the results of tests of the exploded Wilt boiler plates, but no results are recorded by the committee of tests for ascertaining the elasticity of the metal under strain—an essential requisite of good boiler plate.

No tests of either set of experiments show a tensile strength less than 40,000 lbs. per square inch, and with such material it is easy to figure up a resistance in the Wilt boiler of over 300 lbs. per square inch of boiler pressure under uniform temperature of all the parts. As this boiler carried a pressure of not over 80 lbs., to which the safety valves were adjusted, there would be still a factor of safety of near 4 to 1, which ought to hold securely against rupture.

In view of all these facts, there appear two presumptive causes favoring rupture—diminished elasticity in the metal, and strains far

beyond those of boiler pressure, induced by the irregular action of the heat upon the boiler shell.

The writer further says that the Hartford Boiler Insurance Company objects to necks made of material heavier than that in the boiler. We most emphatically do, and whenever we are requested to supervise the construction of new boilers shall always so dictate. He also cites an instance where we have boilers insured with cast iron necks. Very true; but he must bear in mind that we have to take boilers as they are, and while a cast iron neck is not a defect sufficiently serious to cause old boilers to be reconstructed (especially where it is used at a low pressure and for light service), it is one that we are bound to remedy when building new ones. We have many boilers of faulty construction under our care, but that is no reason for perpetuating errors in the construction of new ones. We are very glad that he has seen fit to refer to his report on the boilers built for Mr. George Campbell, as events have transpired subsequent to that report which show, beyond question, what the result of his inspection led to. The boilers were built by the Baldwin Locomotive Works, according to specifications furnished by Mr. Barnet Le Van, who was employed by Mr. Campbell as an expert for that purpose. The boilers were of the type known as horizontal tubular boilers. The lower cylinders being 54 inches in diameter and containing 50 4-inch tubes; the upper cylinders were 30 inches in diameter, and they were connected by two 12-inch necks. When the boilers were finished and our inspectors were called in, preparatory to insurance, it was found that the upper row of tubes in the lower boiler came within $8\frac{1}{2}$ inches of the top. Allowing for 4 inches of water above the tubes, the surface for disengaging steam was so small that it was apparent to us that nothing could keep the water at an even height or prevent it from being driven altogether out of the lower boiler at times. We immediately declined to insure the boilers, and so informed Mr. Campbell, who, naturally desiring further light upon the subject, referred the matter to various experts, and among those so consulted was Mr. Nystrom, as shown by the following letter:

" PHILADELPHIA, Aug. 29th, 1879.

" GEO. CAMPBELL, Esq.:

" SIR—Your letter of the 25th inst., asking information about certain steam boilers, was duly received. I have inspected the boilers,

and submit herewith the report on same. Your letter contains three distinct questions, namely, as follows:

"1st. The chief objection offered against them is that there is not sufficient room or space between the top row of flues and the shell or top of boiler, which will cause the water to lift when in operation.

"2d. Are the necks large enough?

"3d. Are the boilers perfectly safe for constant use on my premises?

"REPORT OR ANSWER.

"1st. The height between the flues and top of shell is 9 inches in the centre, and allowing 4 inches of water on said flues leaves 5 inches between the water surface and top of shell. The relieving surface, or water surface, will then be $2.59 \times 14 = 36$ square feet, which is sufficient to pass the steam without lifting the water; some mist or foam may rise with the steam through the necks, but that will at once be evaporated in the superheating vessel above. The water level in the boiler need not vary more than an inch or two above or below the mean level, which is assumed to be four inches above the flues. The objection quoted in the first question is therefore considered to be unimportant.

"2d. The necks are large enough, being $11\frac{1}{2}$ inches inside diameter, or $103.8 \times 2 = 207.6$ square inches, whilst the steam passage from the drum is only 4 inches in diameter, or 12.56 square inches.

"3d. The question if the boilers are perfectly safe for constant use required a perfect examination of their construction, workmanship and materials, in order to find out their weak or weaker points, which examination has been made, and it is found that the unions of the necks with the shell and drum are their weakest points, or the points where the boiler would first give way, or burst, under excessive strain. These unions, however, are as strong, if not stronger, than generally made in boilers of the same class. The extra good quality of materials and workmanship with which the boilers are made make them much stronger and safer than are other boilers of similar construction.

"(Signed)

JOHN W. NYSTROM."

Now what was the result? Encouraged by such teaching as the above, Mr. Campbell was induced to put in two of the boilers as at first constructed under Mr. Le Van's specifications, and when they were fired up the effect was precisely that foretold by our inspector, and the water, instead of showing a variation of an inch, as stated by

Mr. N., a 12-inch glass gauge was not long enough to keep track of it, and no amount of persuasion could keep the water in the lower boiler when fired as originally intended. After several ineffectual attempts to remedy the fatal defects, the boilers were placed in the hands of the Hartford Boiler Insurance Company for such reconstruction as we thought necessary to make them work satisfactorily.

The reader is referred to the illustrations, Figs. 3 and 4, herewith reproduced from the October number of the JOURNAL, for comparison. They will show which they represent, the boilers originally made for Mr. Campbell, or those now in use at his factory.

Fig. 3.

Fig. 4.



At our direction the Le Van boilers were entirely overhauled, changing their length to 18 feet instead of 14, and putting in 28 $4\frac{1}{2}$ -inch tubes, leaving a clear space of 18 inches from top of tubes to shell of boiler. We also enlarged the necks, to save putting a man-hole on the top of the lower boiler. It was at this point that we stipulated what thickness of material should be used in the necks.

Three of the boilers, as altered under the supervision of the Hartford, are now in place and running, giving entire satisfaction in every respect.

White Shellac Varnish.—Dissolve 1 part pearlash in about 8 parts water, add 1 part shellac and heat the whole to the boiling point. When the lac is dissolved cool the solution and impregnate it with chlorine until the lac has all settled. This precipitate is white, but the color is due to the washing and starching. When it is dissolved in alcohol it forms a varnish which is as transparent as any copal varnish. — *Fortsch. der Zeit.* C.

PERREAUX'S STEAM TRICYCLE.

By LEWIS S. WARE, M. E.

It is to be regretted that up to the present day but little has been done for the general improvement in the type of the tricycle, and the friction of the wheels, on general principles, is such that the advantage over the bicycle does not in any way exist. It is true the principles of equilibrium need not be understood, but the animal force consumed to cover a given number of miles is an item of the first importance when practical work is considered. In view of the fact that with a bicycle a mile has been made in less than three minutes, and 110 miles in less than 8 hours, this system of locomotion is not without interest. At the Paris Exhibition and since, Mr. Perreaux before our eyes mounted his tricycle, moved by steam, and evidently a certain progress has here been realized. The steam bicycle, also an invention of this gentleman, requires less power; 15 to 18 miles per hour has been accomplished with it. The tricycle, that we will now examine (see Fig. 1), has less speed, it going 10 to 13 miles per hour. Supposing the steam generator but moderately heated, the pulling force of this type is 13·2 lbs. The heated air from the generator, etc., moves in an opposite direction to the vehicle, and in no way interferes with the comfort of the rider. The cylinder of the motor has an interior diameter of 20 to 30 mm. (0·78 inch to 1·18 inches), with 80 mm. (3·14 inches) stroke of piston. The distribution of steam is accomplished by a slide-valve, opening and closing at points corresponding to the extreme travel of the piston.

The water-pump can be worked by a small side lever, and with but little care the water level in the boiler can be kept constant, or nearly so; it being sufficient to regulate the pump in such a way that the amount of steam utilized and escaping be replaced by an equivalent volume of water.

The pressure necessary to carry an ordinary sized man is three atmospheres and a half. Belts of cord or leather, or a chain can communicate the movement to the wheels. The inventor claims that he has discovered a new principle of superheating with dry steam, and of the transformation of the latter into work; the problem being to force, in a given

time, the greatest amount of heat into the boiler, consequently to transform water into wet steam, the wet steam into dry steam, the latter into heat, and the heat into work. In heating a boiler containing water, each molecule should absorb a given amount of caloric; the

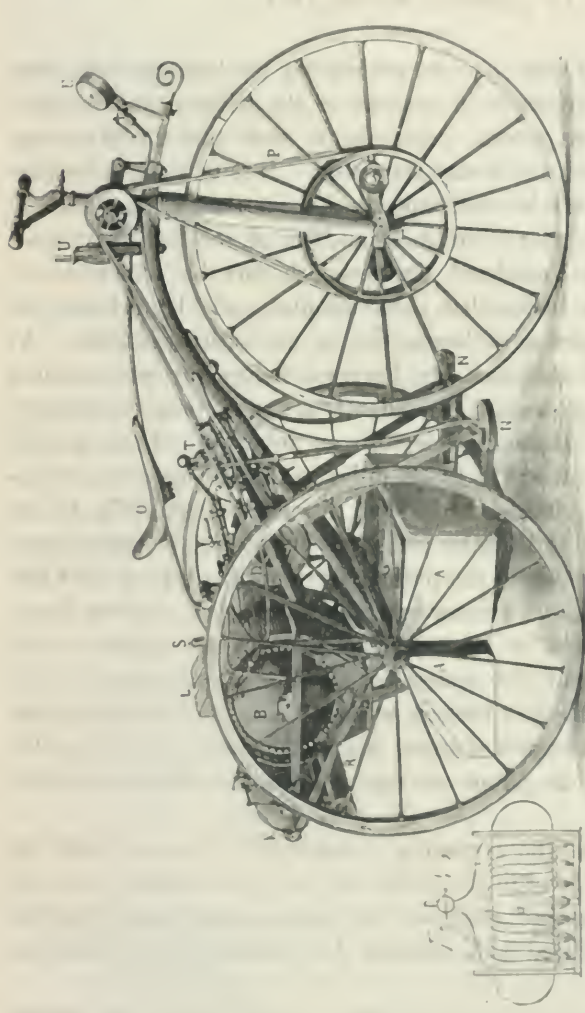


Fig. 1. GENERAL VIEW.

- T*—cylinder.
- t*—reservoir for water.
- f* and *f'*—box for storage of baggage.
- N* and *N'*—supports for the feet.
- Fig. 2. *a* and *a'* are tubes superheated, coiled in spiral on the boiler.
- b* and *b'*—show where the tubes unite before the distributor.
- c*—shows fire-box heated with gas.

Fig. 2. SECTION OF BOILER.

- Fig. 3. *B*—generator, covered with a non-conducting surface.
- K*—generator, and *R* the lamp.
- O*—seat for rider.
- L*—pressure gauge.
- I*—chimney of the generator, and *S* the whistle.
- T*—system to tighten the belts.
- P*—cord belts placed on each side of the wheel.
- D*—crank wheel of the motor.

greater this absorption, the nearer we are to a solution of the problem. Those in contact with the heated surface will move in consequence of the existing local temperature, and will rise to the surface. Evidently, under these circumstances, the molecules that are submitted

to the greatest heat will be the first to evaporate, and will thereby undergo various transformations, depending upon this heated surface.

Mr. Perreaux considers that the intensity of the heat in the interior of the generator will be proportional to a corresponding decrease in wet steam, and that the pressure augments inversely to the primitive densities. To solve the problem of storage of *vis-viva* force in the centre of a reservoir, there are two long spiral tubes, coiled in opposite directions (see Fig. 2), uniting at a point corresponding to the distributing pipe.

These tubes, being coiled on the boiler, will, as proved by experiment, yield better results than any other known similar combination, as the storage in each ring, even at a low pressure, is proportional to the number of coils.

The inventor goes so far as to assert that, with a thermometer as a test, the *heat* co-efficient in the steam pipe is doubled. For example, the steam at low pressure under ordinary circumstances is 82°C . (179°F .), and in this case is 150 to 160°C . (302 to 320°F .), representing 50 per cent. economy of water and heat, without considering that this type of boiler requires less fuel than those that have been previously adopted. At a pressure of three atmospheres the amount of work that can be accomplished is equivalent to that of six of wet steam. By supposing that the temperature increases the entire length of the coil, the wet steam decreases in the same ratio. Consequently the steam, being at a higher temperature, will give a higher mean effective pressure. Condensation of steam in the cylinders, the inventor contends, no longer exists, and the purging cock is not required. The expense of running the machine is three cents per mile by burning alcohol. What actual value this tricycle or its theories have remains yet to be seen.

The St. Petersburg Canal.—The projected ship canal, to avoid the bar across the mouth of the Neva, will have a depth of nearly 19 feet, and will be connected with a system of basins, docks and railway lines, at an estimated cost of \$6,800,000. When it is completed St. Petersburg will become the great commercial centre of Russia, while Cronstadt will be exclusively a military port. At present fully two-thirds of the merchandise destined for the capital has to be transhipped at Cronstadt into small vessels.—*L'Ingen. Univ.* C.

CELLULOID—WHAT IT IS, AND HOW IT IS MADE.

By W. H. WAHL, Ph.D.

The multifarious uses which this remarkable substance is made to serve, and which appear to be constantly increasing, as well as the fact that but little is generally known concerning its composition or the methods of producing it, render it probable that a few words concerning it may prove of interest to many of our readers.

Celluloid, briefly defined, is a species of solidified collodion, produced by dissolving gun-cotton (pyroxylin) in camphor with the aid of heat and pressure.

The nature of this product and the methods of procedure employed in its manufacture will be found described in what follows. First, let us devote a few lines to an account of the materials employed; and here, as of prime importance, we must begin with gun-cotton.

When cellulose, or wood fibre (under which terms are included common cotton, paper or paper-pulp, the refuse of cotton mills and vegetable fibre of every description), is immersed for a few minutes in a bath composed of a mixture of strong nitric and sulphuric acids, then removed and washed and dried, it will be found to have acquired new and remarkable qualities. In external appearance there is nothing to indicate that any change has taken place, but when the test is made it will be found to have become highly inflammable, and (if the action of the bath has been sufficiently prolonged and intense) even highly explosive. Wood fibre, or, to give it its proper chemical name, cellulose, thus treated, is said to have been nitrated, and the resultant product is termed nitro-cellulose, pyroxylin, or, properly, gun-cotton. The latter term is given to it because, when properly prepared, it can be used as a substitute for gunpowder, having explosive qualities considerably greater than the latter. A number of substances besides cellulose, when treated in the manner above described, acquire similar inflammable or explosive properties, among which may be named sugar, starch and glycerine; the nitro-compound of the last-named substance being nothing else than that most terrible and energetic of known explosive agents—nitro-glycerine.

Besides acquiring inflammable and explosive properties, our cotton

(supposing, for the sake of illustration, that we have used this common form of cellulose), after treatment as above described, has taken on another quality, namely, that of ready solubility in certain menstrua which are utterly without action on common cotton. For example, it will be found to gelatinize and quickly disappear in a mixture of alcohol and ether, forming a thick, transparent liquid. This is the same material used by photographers, who, in taking a picture, first spread a thin film of this solution, called collodion, upon a glass plate. The ether and alcohol being volatile quickly evaporate, leaving behind a thin, smooth and tenacious membrane or film of gun-cotton, which serves as the medium of holding the sensitive silver compound used in taking the photographic image. It is upon this property of ready solubility of gun-cotton that the manufacture of "celluloid" depends, as we shall presently see; and the secret of its production depends upon the fact that camphor, like ether and alcohol, will readily dissolve gun-cotton. Prof. Seely, so far as the writer is informed, was the first to observe that gun-cotton would dissolve in an alcoholic solution of camphor, and the brothers Hyatt after many experimental trials, succeeded in perfecting and patenting a procedure, whereby camphor, with finely pulped gun-cotton, is made to exert its solvent effect upon its substance, with the aid of heat (fusion) and pressure in a closed chamber (to prevent the volatilization of the camphor). The following is an abstract of their method:

Gun-cotton is ground in water to a fine pulp in a machine similar to that used in grinding paper pulp; the pulp is then subjected to powerful pressure in a perforated vessel, to extract the bulk of the moisture, but still leaving it slightly moist for the next operation. This consists in thoroughly incorporating finely comminuted gun-camphor with the moist gun-cotton pulp in the condition last named. The proportions employed are said to be one part by weight of camphor to two parts by weight of the pulp.

With the camphor and pulp, the patentees further state they also incorporate any pigments, coloring matter, or other materials that may be adapted to the requirements of the articles into which the product is to be manufactured.

The mixture of pulp, camphor and pigments having been made, the next step is to subject the mass to powerful pressure, in order to expel from it the remaining traces of moisture, and incidentally to effect also the more intimate contact of the camphor with the pulp.

The dried and compressed mass is next placed in a mould open at the top, into which fits a solid plunger. The vessel is next placed in a hydraulic (or other) press, and heavy pressure, applied to the plunger, is brought to bear upon the mixture. While thus under pressure the mixture is heated by means of a steam jacket surrounding the chamber, or by other means, to a temperature of about 300° Fahr.; at this temperature the camphor fuses and, its volatilization being impossible, the melted gum dissolves the gum-cotton pulp, or, to use the words of the patentees, "converts" it. The patentees further state that the process of transformation is rapidly effected when the right temperature is reached, and the product which results in the homogeneous solidified collodion, known as celluloid. After the mass is taken from the press, it hardens and acquires the extraordinary toughness and elasticity which are the distinguishing characteristics of the product; and one of the most noteworthy circumstances connected with it is the fact that a large portion of the camphor which it contains appears to be permanently held or combined with it, if we may use this convenient (though not strictly correct) term, so that its property of volatilization when exposed to the air is practically arrested.

There are several varieties or modifications of the above-named procedure which would require too much of our space to detail. The process commonly employed in the production of celluloid is substantially that which we have given; and the endless variety of colors that the products of celluloid possess are obtained simply by proper admixtures of pigments in the operation of its manufacture; mottled and other peculiar effects require special manipulation, which our technical readers will not find it difficult to understand. It should be remarked, also, that the celluloid made as above detailed can be rendered plastic again, and remolded into any desired shape without further additions.

As to the applications of celluloid, they are legion, and we can only name the more prominent of them.

As a substitute for ivory it is perhaps best known, and has been so successful as to have been for many uses to which this substance was formerly put so extensively substituted for it, as to have made serious inroads upon the business of the ivory importers and workers. So perfect is the resemblance of celluloid to ivory that a close inspection is required to distinguish the counterfeit from the genuine. The absence of "grain" is perhaps the readiest peculiarity by which goods

of celluloid may be detected, but, for all practical purposes, it is not only as good, but also in some respects better than ivory for all the uses of that substance. It (celluloid) possesses not only all the strength and elasticity of ivory, but it does not warp nor discolor with age.

On these accounts it is now largely used in place of ivory in making piano and organ keys, billiard balls (said to be equal in elasticity to those of ivory), combs, backs of brushes and hand mirrors, plates for ivorytypes, frames for looking glasses and portraits, handles for knives and forks, whips, canes and umbrellas, and other objects too numerous to name for which ivory is used; and not the least of its advantages as a substitute for this substance is the fact that it can be molded, a property which renders it possible to reproduce the most delicate and elaborate decoration on the articles fashioned out of it at a fraction of the cost of similarly ornamented goods of ivory, and some of the other materials imitated.

Hard-rubber, it is said, is able on account of its cheapness to hold its own against celluloid very well; but tortoise shell, malachite, amber, pink-coral, and other costly and elegant materials are so successfully imitated that an expert must look sharply to detect the original from the copy. In imitation of tortoise shell, it is made in such articles as combs, card-cases, cigar-cases, match-boxes, napkin-rings, etc. The pink-coral, so popular for jewelry, is admirably imitated, and the imitation sold at prices considerably below those of the genuine article; and the same may be said of articles imitating malachite and amber. Mouth-pieces for pipes, cigar-holders and musical instruments, cleverly substituting the last named are quite common.

Celluloid is used also as a substitute for porcelain in making dolls' heads that will stand any amount of hard usage. It is used in place of tortoise shell and hard-rubber for the frames of eye-glasses, spectacles and opera-glasses, for shoe-tips in place of metal, for martingale-rings, emery-wheels and knife-sharpeners. The latest thing in celluloid, and certainly the most novel, is its use, in combination with linen, cotton or paper, for shirt bosoms, cuffs and collars. These goods are possessed of a lustre which very cleverly imitates that of freshly laundered linen; they are remarkably strong, elastic and durable, and are completely impervious to moisture, and of course to perspiration. When soiled they require only to be wiped off with a moistened sponge,

or cloth, to have their freshness restored, and can be made to do service for a long time.

What new uses for this extraordinary product the future may develop no one knows, but it is safe to say from what has already been achieved with it, that its production is deserving of a rank beside that of vulcanized rubber, as one of the most remarkable inventions of the age.—*Journal of Industry*.

THE ALLEGED DECOMPOSITION OF CHLORINE.

Dr. H. Endemann, who has written an article in the "Journal of the American Chemical Society," entitled "A Review of the Latest Investigations on the Dissociation of the Elements at High Temperatures," publishes the following letter from Prof. Meyer:

"ZURICH, d. 28 Sept., 1879.

"SEHR GELEHRTER HERR In Erwiderung auf Ihr geehrtes Schreiben vom 12 Sept., theile ich Ihnen mit, dass die Mittheilungen der englischen Journale ueber meine Arbeiten welche ueber Gewinnung von Sauerstoff aus Chlor berichten, ohne mein Wissen und gegen meinen Willen veroeffentlicht sind, und das diese Mittheilungen in wesentlichen Punkten voellig inkorrekt sind.

"Hochachtungsvoll,

Prof. VICTOR MEYER."

[TRANSLATION.]

"ZURICH, September 28, 1879.

"DEAR SIR—In reply to your favor of September 12th, I would state that the communications in the English journals concerning my investigations, which report the separation of oxygen from chlorine, have been published without my knowledge and against my wishes, and that the said communications are entirely incorrect in essential particulars. Respectfully,

Prof. VICTOR MEYER."

Telegraphic Feat.—Not less than 215 despatches, averaging 30 words each, were sent in one hour over a single wire, between London and Birmingham, by means of a quadraphex.—*Frankf. d. Zeit.*—C.

BLAST FURNACE SLAG.

Scattered throughout the iron-making districts of Great Britain are many million tons of scoria, or refuse from the blast furnaces, which is technically known as slag. This slag goes on accumulating at the rate of nearly eight millions of tons per annum, its bulk being some three times that of the iron from which it has been separated. It forms a heavy encumbrance to iron-masters, demanding the purchase of large tracts of land whereon to deposit it, the investment being, of course, wholly unremunerative. There are one or two exceptions to this rule, as at the Barrow Hematite Iron Works, where the slag is tipped into the sea and serves to form land for the works, and at Middlesbrough, where some of the iron works supply slag for the construction of the breakwater and retaining walls in the river Tees. The quantity thus utilized, however, on the Tees is but about 600,000 tons per annum, forming only a small proportion of the whole yield of the district. In some cases, where the iron works are conveniently situated, the slag is carried out by barges and tipped on to banks at high water to form retaining walls or to reclaim land, being thus got rid of. But, as a rule, the labor and capital expended upon this unproductive substance tell heavily upon profits. No wonder, then, that from the first, persistent efforts have been made either to utilize it or to get rid of it altogether. In early times, slag was broken up by hand and used for road-making, and it so continues to be used where it can be had without a heavy cost for transport; but there is only a limited demand for it for this purpose. On the Continent, where stone is scarce, slag plays a prominent part in road-making, as in Silesia and other similarly situated districts. Another direction in which many attempts have been made to utilize slag, both at home and abroad, is to adapt it for constructive purposes, and various schemes have been devised for transforming the highly refractory slag into bricks, sand, and other materials for building. Some of these schemes have proved successful within certain limits; but the peculiar nature of the slag has more generally led to failure, owing either to the difficulty of dealing with it or the attendant expenses. Among the most prominent living scientific investigators of the question was Mr. Bessemer, and about fifteen years since Mr. John Gjsers devised a method of granulating

slag, the sand produce being used in place of silicious sand on the pig beds. The practice, however, was discontinued after a time, for technical reasons. Several other practical men have taken an active part in endeavoring to solve the slag difficulty, among them being Mr. D. Joy, Mr. T. Bell, Mr. Lürmann, and Mr. Homer. Some time since Mr. Charles Wood, of Middlesbrough-on-Tees, directed his attention to the utilization of this unproductive material, and after about five years of careful study, experiment and practical research, he has succeeded in effecting the conversion of blast-furnace slag into various forms, and in applying it to several industrial purposes upon a practical and commercial scale. At the time when he started upon his investigations there was no instance of slag being manufactured into a commercial commodity in this country, its only known application being that of road-making. Mr. Wood, however, has succeeded in utilizing it for the manufacture of building bricks, concrete, cement, mortar and slag-wool. The various processes of conversion and manufacture are carried on under Mr. Wood's management at the Cleveland Slag Works at Middlesbrough, which, together with the adjoining Tees Iron Works, belong to Messrs. Gilkes, Wilson, Pease & Co., of which latter works Mr. Wood is also the manager, and whence the slag is obtained. In following the highly interesting processes of conversion consecutively, we must first take our readers to the iron works, where the slag is run from the blast furnaces into two different machines, one of which produces a coarse kind of shingle and the other a fine sand. For making shingle the liquid slag is run direct from the blast furnaces on to a circular, horizontal, rotative table composed of thick slabs of iron kept cool by having water circulated through them. The table, which revolves slowly, carries the slag round to a certain point, by which time it has solidified. At that point it encounters a stream of water, which further cools it, and soon after it comes against a set of scrapers, which break it up and clear it off the table, delivering it into wagons placed below, which convey it away. For producing slag-sand, the slag is run from the blast furnace into a hollow wheel revolving upon a horizontal axis and fitted with iron buckets inside. A bath of water is maintained inside the wheel at the bottom, and is kept in a state of violent agitation by the revolving action. As the molten slag enters the body of water it is immediately disintegrated and assumes the form of sand, the water taking up the heat from the molten slag and giving it off in the shape of steam. A

constant flow of water is maintained into the machine, and the sand is separated from it and elevated to the top of the machine by the bucket plates, which are perforated. Arrived at the upper part of the machine, the slag sand is dropped into a spout, and thence finds its way into wooden wagons, by which it is conveyed to the slag works for manufacture.

The slag works occupy a main building 120 feet long, 50 feet wide, and five stories high, with basement beneath, and engine house, boiler house, and other accessories annexed. This building was constructed of slag cement-concrete, composed of four parts of slag shingle to one part of cement, and it forms a very solid and comparatively indestructible structure. The slag-sand is brought here from the blast furnace and is tipped into stores below, whence it is elevated to the top floor by means of a hoist, which is fitted with an ingenious automatic safety brake designed by Mr. Wood. The special manufacture in this building is that of bricks, and in carrying this out two machines are used, one having been designed by Mr. J. J. Bodmer and the other by Mr. Wood. For the Wood machine the sand is delivered into a hopper through a coarse screen, which retains any pieces of slag or other substances which may have found their way into the sand. Arrived at the floor below, the sand is automatically measured on a revolving cylinder, divided on the outside, and placed at the bottom of the hopper. From another hopper selenitic lime in powder is also measured by a similar contrivance, and the two substances unite in one shoot, where they become mixed in the proportion of ten parts of sand to one of lime. The mixture is carried down a hopper into the pug-mill of the brick-making machine, where the two substances are further incorporated. This machine was designed by Mr. Wood, and is the outcome of considerable experience with another machine to which we shall presently refer, and which it has to some extent superseded. Mr. Wood's brick machine has a horizontal, circular, rotating moulding table, which contains six pairs of moulds, four bricks being pressed at the same time. During the time of pressing—which is effected by direct mechanical pressure—the table remains stationary, and the same time four other moulds are being filled and the remaining four are delivering the pressed bricks. As they are delivered they are taken off the machine by two girls and are removed to an air-drying shed—the machine producing from 11,000 to 12,000 bricks per day. There they remain for a week or ten days, after which they are stacked in

the open air to harden, which occupies another five weeks or so, when the bricks are ready for the market. The bricks thus produced are very tough; they do not split when a nail is driven into them, and are largely used for interior work, for which they are well adapted from the regularity of their surface and other qualities. They find a good market in London, and are not subject to breakage in transit. According to a certificate recently issued from Kirkaldy's testing works, some bricks taken from a stock, three years old, were not crushed until a pressure of 21 tons had been reached. Others taken from a stock four months old were crushed with nine tons pressure, thus showing not only unusual toughness and strength, but that they were greatly improved by age. We thus have the curious anomaly of bricks being made without burning and of a wet season being favorable to the hardening process. The second machine at the Cleveland Slag Works is that of Mr. J. J. Bodmer, and was the first one put up at the works. It is worked by hydraulic power, and has a horizontal revolving table with twelve moulds. The slag sand and the lime are mixed on their way to the machine, but the machinery for effecting the mixing is more complex than that used for Mr. Wood's machine. The rate of production in the Bodmer press is about the same as in the Wood machine, the distinctive difference between the two presses being that the former is worked by hydraulic power, and the latter by direct mechanical pressure, Mr. Wood's machine possessing several advantages over that of Mr. Bodmer. In another department the manufacture of artificial stone is carried on, the stone being moulded into chimney-pieces, window-heads, balustrading, and outside ornamental builders' work generally. The stone is composed of two and a half parts of finely pulverized slag and two and a half parts of ground brick to one part of Portland cement. The mixture is run into moulds and sets quickly, the articles being ready for the market in four or five days. Besides bricks and stone articles, the slag is used for making mortar, cement and concrete. The mortar is a mixture of slag and common lime, the cement being composed of the same materials with the addition of iron oxides. Slag cement also forms the subject of a recent invention by Mr. Frederick Ransome, who has produced some very remarkable results.

Perhaps the most beautiful, and certainly not the least remarkable, outcome of blast-furnace slag is slag-wool, or silicate cotton, as it is also called, owing to its resemblance to cotton-wool. The process origin-

ated, we believe, with Messrs. Siemens Brothers, on the Continent, and the manufacture has been before attempted in England, but, as far as we are aware, has not succeeded. As carried out by Mr. Wood, at the Tees Iron Works, a jet of steam is made to strike against the stream of viscous molten slag as it is run off from the blast furnace. This jet scatters the molten slag into a stream of shot, which is projected forwards near the mouth of a large tube, in which a couple of steam jets cause an induced current of air. This tube opens into a receiving chamber, composed chiefly of wire gauze, and measuring about 33 ft. long by 15 ft. wide and 12 ft. high. As each shot leaves the stream of slag it carries a fine thread or tail with it. The shot, being heavy, falls to the ground, while the fine woolly fibre is sucked through the tube and deposited in the chamber. The appearance of this chamber after a charge has been blown into it is singularly beautiful, the floor, sides and roof being covered with a thick layer of the downy silicate cotton. After each blowing the wool is removed by forks, and packed in bags for consignment to a London firm—Messrs. Daniel Dade and Co.—who make it into mattresses which are used for covering steam boilers and for other purposes where it is desired to prevent the radiation of heat. For this purpose slag-wool is eminently adapted, as it is a very bad conductor of heat, and is, moreover, perfectly incombustible. The make of slag-wool at the Tees Works is about three tons per week, and as during the running of a four-ton slag ball about $1\frac{1}{4}$ cwt. of slag-wool is made it follows that for producing these three tons nearly 200 tons of slag have to be operated upon. Another useful purpose for which blast furnace slag has been successfully utilized is that of glass manufacture. The vitreous character of slag indicates a resemblance to glass in its composition. It does, in fact, contain the principal components of glass, but not in proper proportions, and those in which it is deficient have therefore to be added with others which are not present. Some years since Mr. Bashley Britten investigated this question, and in the end succeeded in utilizing for the manufacture of glass not only the material, but also the heat of the slag. This latter is a very important point, inasmuch as upon it depends the economy of the utilization, and, therefore, its commercial success. The practical result of Mr. Britten's researches was the establishment by a company, of some works at Finedon, in Northamptonshire, where the manufacture of glass bottles from slag is now and has for some time past, been regularly carried on. The glass works are situated in close contiguity to

the blast furnaces of the Finedon Iron Works, where the Northamptonshire ore is worked, and as the molten slag is run from the furnaces it is conveyed in carriers to the glass works. In these works a Siemens regenerative gas furnace applied to a glass melting tank enables the preparation of the "metal" to be carried on continuously, affording a constant supply to the glass blowers. The ingredients of the glass are fed into the tank in charges of about 500 lbs., the larger half of which is the molten slag, the remainder being the other necessary ingredients, such as sand and alkalis. In the tank these substances are fused and fined, the fused metal flowing through a bridge to the other end of the tank, where there are five working holes, from which the metal is taken by the workmen and fashioned into useful articles in the usual way. For the present the manufacture is confined to wine and beer bottles, of which about ninety gross can be produced per day. So far the results have proved sufficiently satisfactory to induce the company to extend their works, plans for which are in course of preparation. It is proposed to erect not only additional furnaces, but plant for the manufacture of other articles besides bottles, and for these a wide field opens itself. The glass produced is said to be stronger than ordinary glass, and the color can be varied as required, the natural tint being green. Its working qualities are said to be of the highest order, as it comes from the furnace in the best possible condition for the worker. Some bottles made at Finedon were sent to the Paris Exhibition last year, where they obtained honorable mention, a testimony at once to their character. A new method of toughening glass has recently been discovered by Mr. Frederick Siemens, of Dresden, and it is proposed to apply this process to slag glass for the purpose of manufacturing railway sleepers and other articles. Details of Mr. Siemens' process are not at present to hand, but, judged by results, it would appear to differ from that of M. de la Bastie, inasmuch as when the toughened glass is broken it does not fly into minute atoms as does De la Bastie's, but simply fractures, somewhat similarly to cast iron.—*London Times*.

Brazilian Telephones.—In Brazil telephonic communication has been established among many of the large plantations, different private parties, and government offices. At Rio de Janeiro Gowen telephones are used for sending messages between the Senate and the lower house.—*Les Mondes*.

RANSOME'S NEW HYDRAULIC CEMENT.

As is well known, the materials employed in the manufacture of "Portland" cement are clay obtained from alluvial deposits—such as is to be found on the banks of the Thames and Medway—and chalk, these materials, after being ground together in water (to produce the mixture known technically as slurry) being burnt with coke in a kiln at a high temperature. Of late years the details of this process of manufacture have been much improved, and numbers of the leading firms are now supplying regularly cement having fully twice the strength of that which could be obtained only a few years ago; but notwithstanding this the materials used have remained the same as those employed when Portland cement was first introduced by Mr. Joseph Aspdin, of Leeds, to whom a patent was granted in 1824.

When employed in decorative purposes a great objection to Portland cement is its color, this objection—which is due mainly to organic and other matters mixed with the materials employed—being particularly strong when the cement is exposed to wet or moisture. It was to removing this defect of color, while retaining the other properties of Portland cement, that Mr. Ransome's experiments were first directed, and, as we mentioned in our former notice, he succeeded in the production of a cement which, while having great strength, was absolutely colorless, or which could be tinted as desired.

Mr. Ransome commenced his operations by substituting previously washed kaolin for the Thames or Medway deposits, and burning the mixture in retorts or muffles, so that the material was protected from the direct action of the heated products of combustion. By this means he obtained a beautiful white cement, which in the course of a few hours set remarkably hard, and was capable of receiving a polish resembling Carrara marble. He found also that the material was still further improved by the addition of a portion of soluble silica obtained from some of the natural mineral deposits, such as the beds near Farnham, or preferably from the deposits in the New England States on the other side of the Atlantic. The relative proportions of lime, alumina, and silica which he found to be desirable in the mixture after burning, were: lime, 60 parts; alumina, 12 parts; and silica, 22 parts. When a tinted cement is required instead of a white, the desired color

can readily be obtained by the addition of pigments, such as ochres or iron oxide, during the grinding.

Although the results obtained by the process just alluded to were in every respect most satisfactory, as regards the material produced both in point of hardness and general appearance, it soon became evident that however valuable this cement might be in an æsthetic point of view for decorative and artistic purposes it could not be produced at a price to render it commercially available for the numerous constructive purposes for which the well-known Portland cement is now so deservedly in demand. Under these circumstances, in casting about for the best source of supplies of silica and alumina in a condition most favorable to enable them to combine readily with lime at a comparatively low temperature, Mr. Ransome was led to the conclusion that the very thing required was to be found in any quantity, and capable of being supplied at a cheap rate and in a very favorable condition, as a by-product which is now of little or no value, and that is blast furnace slag, which consists of silica, alumina and lime.

Many attempts have been made by various parties to utilize this material in the process of manufacture of cement, but the cost attendant upon the reduction of the slag to a sufficiently fine state to combine properly with the additional lime with which it had to be mixed, baffled all attempts to produce with it a good cement at a price that could compete with the Portland cement now in general use. The difficulty of dealing with the furnace slag was, however, removed by the invention of Mr. Charles Wood, of the Tees Iron Works at Middlesbrough, who, in the year 1873, obtained a patent for granulating slag by running it direct from the furnaces into water. This granulated slag, or "slag sand," as it was called by Mr. Wood, was found on analysis to contain:

Silica, ...	38.25
Alumina, ...	22.19
Lime, ...	31.56
Magnesia, ...	4.14
Calcic sulphide, ...	2.95
Protoxide iron, ...	.91

The slag sand so produced is of a most agreeable light buff color, and may be easily reduced to the finest powder by pressing between the fingers and thumb, and by mixing one part of it intimately with from one to two parts by weight of chalk or limestone, and burning

the mixture at a moderate temperature, there is produced an eminently hydraulic cement, which compares most favorably with the best manufactured Portland cement of the present day. It may be noted, as an especial advantage attending the employment of slag sand in this way, that, the materials composing it having already been thoroughly burnt together in the blast furnace, the severe burning required in the ordinary process of cement manufacture is rendered unnecessary.

Comparative Tests of Strength between Portland Cement, weighing 123 lbs. per Bushel, and Ransome's New Hydraulic Cement.

Age.	Breaking Strain of Samples $1\frac{1}{2}$ Inches Square, giving a Sectional Area of $2\frac{1}{4}$ Square Inches.	
	Portland, 123 lb. per bus.	Ransome's Patent.
	lbs.	lbs.
2 days, ...	510	740
3 "	698	870
7 "	818	1170
12 " . . . . .	.....	1300
15 " . . . . .	.....	1330
21 " . . . . .	.....	1440
28 "	936	
3 months, ...	1056	
6 "	1176	
9 "	1219	
12 "	1229	
2 years, ...	1325	
3 "	1314	
4 "	1312	
5 "	1306	
6 "	1308	
7 "	1327	

Samples of Mr. Ransome's new cement have recently been carefully tested at the cement works of Messrs. Gibbs and Co. of Grays, under the direction of the manager, Mr. D. Lincoln Collins, and we annex a table, in which the result of these trials are given side by side with those obtained from an exceptionally good quality of Portland cement, the figures relating to the latter being derived from the valuable experiments of Mr. Grant, who by his practical researches has done so much to elevate the quality of Portland cement during late years. It will be noticed that in the table the results relating to the Ransome cement only extend to samples 21 days old; other older samples will,

however, shortly be experimented upon, and we hope to lay the results from time to time before our readers. Meanwhile it may be noted that, even when fifteen days old, the new cement had attained a higher strength than was reached by the Portland cement in seven years, while it is further particularly to be noticed that the Ransome cement shows a steadily increasing strength with age, so that the sample 21 days old was probably far from possessing the tenacity which will ultimately be attained. Altogether Mr. Ransome appears to have produced a very valuable addition to our constructive materials, and we shall watch the future development of his invention with much interest.—*Engineering*.

New Kinds of Plated Sheet Iron.—In Iserlohn, Westphalia, thin sheet iron is plated with alloys of nickel or cobalt and manganese. A half of one per cent. of manganese makes cobalt and nickel very malleable, fluid when melted, and ductile. The plates which are already in the market are beautifully white and brilliant.—*Metalworker*. C.

Local Earthquakes.—The earthquake of Lisbon, in 1755, was felt over a surface of 40,000,000 sq. kilom. (15,366,000 sq. m.) or over a twelfth part of the earth's surface. Such extensive shocks are generally attributed, by geologists, to volcanic action. Observers at the centre of the disturbed area perceive a vertical oscillation; the movements become more oblique on going from the centre, the waves being propagated with a regularity which is not observable in the ordinary local earthquakes of non-volcanic countries. Dr. Thiessing, in discussing some of the Swiss earthquakes, considers the amount of inorganic matter that is brought to the surface by mineral springs. It has been estimated that a single spring in Louèche (Lenkerbad) annually brings 4,000,000 kilog. (8,818,485 lbs.) of gypsum to the surface, or about 1620 cubic metres (2119 c. yd.), a quantity sufficient to lower a surface of a square kilometre (1196·03 sq. yds.) more than 16 decimetres (5·25 ft.) in a century. In the valley of Viège there are not less than a score of gypsiferous springs, each of which carries off annually 200 cubic metres (261·6 c. yds.) of mineral. If we think of the thousands of fountains, and the immense duration of their flow, we may form some idea of the importance of the transformation caused by their waters, and the violent superficial oscillations to which they give rise.—*Bull. de la Soc. Indust.* C.

Bower's Rust-Preventive.—Carbonic acid, generated by the combustion of carbonic oxide, is allowed to act upon iron or steel at a moderately high temperature; or, a layer of sesqui-oxide is first produced, and a mixture of carbonic acid and air is afterwards passed over the red-hot metal.—*Berg- u. Hütten-Ztg.* C.

Proposed Adoption of the Egyptian Cubit.—In noticing the labors of the International Bureau of Weights and Measures, Abbe Moigno regrets the choice, as unit of measure, of the ten-millionth of a meridional quadrant, "a unit fatally indeterminate," since the meridians vary in length. He suggests, as a better standard, the cubit of the Great Pyramid, which represents the ten-millionth of the earth's polar axis. Sir John Herschel made the same proposal, nearly thirty years ago, and it is somewhat remarkable that his views should be now advocated by a leading French scientific journal.—*Les Mondes.* C.

Thermo-Electric Steel Tests.—Carl Barus has studied the thermo-electric disposition and the electric conductivity of steel, in their relations to the hardness of the steel. He finds that if a steel rod of uniform known hardness is broken in two and the two original ends connected with a galvanometer, the hardness of pieces of steel can readily be tested. For if the free ends of the test rod are laid on the sample of steel which is to be tested, and either point of contact is heated (*e. g.* with a small jet of steam), the thermo-current will flow from the test-rod if it is harder, and to the rod if it is softer than the sample.—*Wied. Ann.* C.

Book Notices.

A MANUAL OF POWER FOR MACHINES, SHAFTS, AND BELTS With the History of Cotton Manufacture in the United States. By Samuel Webber, C. E. New York: D. Appleton & Co., 1879. 2 parts; 124 and 105 pages.

This purely technical work is of the highest interest to the cotton manufacturer in the statement of results of many thousands of tests, by a dynamometer, of the several special machines used in this branch of industry. It may be supposed that the various openers, lappers, cards, draw frames, slubbers, . . . slashers, looms, etc. etc., are well-

known invariable standard machines in cotton mills, so that comparisons of dynamometer values, ascertained with some suppressable uniformity of conditions of machines, belts and lubricators and lubricants, can be instituted. The 87 pages of tables of information of this class then become available and important to cotton mill owner or operator. The tables of summaries of power for cotton mills for production of different grades of goods, would be more satisfactory if real examples of mills actually at work could have been found to corroborate the totals. But it must be admitted that careful detailed estimates of this class do give a close approximation to accurate results. Beside the tests of cotton machinery, a series of tests of machines for other textile substances: woolen, worsted, flax, etc., will be found more or less extensive and useful.

The two chapters relating to shafting and belting are very incomplete in giving information either to the mill operator or to the general mechanician. Neither generally or in detail, are these subjects considered in a practical point of view. The chapter relating to shafting is peculiarly imperfect. Does the author mean to assert that it is good practice to transmit 18 horse power by a long line of two-inch, cold-rolled shafting running 300 revolutions per minute in swivel bearings, placed 17.7 feet apart, with the usual alignment of bearings in a cotton mill? The want of any consideration of the nature of bearings, in the relation of surface to velocity and pressure, and of consideration of velocity to economic dimensions of pulleys and belts—dimensions derived from the power to be transmitted, as well as from some limit of sizes and strength of belts and convenience in operating, makes it questionable if the omission of the chapter would not improve the work as a work of reference.

The chapter relating to belting with its following table is more seriously erroneous yet. There is no great divergence from the facts, in the assumption that an inch wide leather belt in average condition, at a speed of 600 feet per minute, and having a contact with a turned iron pulley of 180° (or half the circumference) will transmit one horse power. But this will *not* occur at another speed or another angle. The writer of the manual asserts "The most scientific writers commit gross errors in treating of this question." On the contrary, all scientific writers are in accord on the subject and are absolutely correct in their deductions. The only question left open by them is: what is the proper coefficient of adhesion of a leather belt to a pulley? With the

usual caution of a computer each writer has accepted as a safe estimate a low value for this fraction, although he may have got a high one by experiment. The conclusions heretofore reached have given what we now know to be inordinate width for belts.

At the risk of prolonging this notice, an attempt will be made to give a popular account of the theory of belt transmission. A leather belt imparts motion to a pulley upon which it is laid and around which the belt is put in motion, because of the adhesion of the leather to the pulley surface in place of sliding over the same. This adhesion arises from the pressure of the belt upon the pulley, and bears a definite proportion to that pressure. What the value of such proportion may be is called the co-efficient of adhesion, or of friction. Thus if a belt were to exert a pressure of 10 pounds per square inch, and if the belt had 35 inches of contact (say a belt one inch wide bearing 25 inches long on a pulley) the total pressure would be 250 pounds. Experiments have shown that about 146 pounds pull must be exerted on such a belt to cause it to slip, and the co-efficient of adhesion becomes $146 \div 250 = 0.583$. In the case of a belt imparting motion, however, the pressure is not uniform, as here assumed. As this pressure *proceeds* from the tension on the belt, and this tension obviously differs on the two sides of the pulley (from the loose to the tight side), a gradual change of tension must occur in the belt on the pulling surface; and a gradual increase of pressure, inch by inch, on that surface. Each particular pressure has its own constant rates of adhesion, augmenting the tension to produce greater pressure. The first adhesion being that coming from the strain on the slack side, while the last adhesion completes the total of strains exerted on the tight side of the belt. To use the words of the writer of the manual, "This will be understood by those who know the enormous hold given by passing the rope from a pulley block once [or twice] around a post where the whole surface is in contact."

The force exerted by a belt is the difference between the strain on the two sides. The greatest strain on a belt is equal to the force exerted, added to the strain on the loose side. The greatest strain *proceeds* from the exertion of sufficient strain on the slack side of the belt to give the requisite adhesion. Same as the exertion of some pull on the rope is needful to keep the rope from rendering around the post when a weight is held by a pulley block, as in the writer's supposed case. The adhesion does not vary directly with the arc of the circle with

which the belt is in contact, but it follows a complicated logarithmic equation derived from the summation of the successive increases of pressure on the pulley surface, as the belt passes from slackness to tightness.

The undetermined element in the text books generally is the coefficient of adhesion, and this element is not yet settled. Let us see what effect a variation of the accepted coefficient will have upon the assumption that 600 feet velocity per minute of a 1-inch belt will be the equivalent to one horse power; a condition which calls for the exercise of 55 pounds *excess* of strain between the tight and slack sides of the belt.

In January of 1868, and the following month, there was published in the JOURNAL OF THE FRANKLIN INSTITUTE a paper by Messrs. Briggs and Towne in which it was attempted to show that a high coefficient of adhesion might be accepted as conforming to common practice. The experiments then published gave $f=0.583$ (Gen'l Morin in his *Mechanics* (Bennett's trans. 1860) found $f=0.573$ for a maximum of adhesion of leather to iron). Messrs. Briggs and Towne computed tables based on $f=0.423$, which have met general acceptance as practical accomplishments.

Taking their value as a probable one, and going downward to $f=0.20$, the following table gives the strains corresponding to 55 pounds *force* upon 180° of contact:

I.	II.	III.	IV.	V.	VI.
Ratio of adhesion of leather to smooth iron—assumed.	Effective force given by 1 inch width of belt running one foot per minute—pounds	Angle of contact upon pulley	Tension on tight side of belt, derived from data—pounds	Tension on loose side of belt, derived from data—pounds	Tension on belt—both sides with 180° contact—pounds
0.583	55	180°	65.45	10.45	37.95
0.423	55	180°	74.8	19.48	46.64
0.4	55	180°	77	22	49.50
0.35	55	180°	82.5	27.5	55
0.3	55	180°	90	35	62.5
0.25	55	180°	101.1	46.1	73.6
0.2	55	180°	117.8	62.8	90.3

This table simply exhibits that if an inch wide belt, with 180° contact, is strained to the several tensions shown in column VI, and then it is operated so as to give out one horse power at a velocity of 600 ft.

per minute, there will be called into action the respective coefficients of adhesion given in column I.

Perhaps a more ready understanding of the nature of the action of a belt on a pulley may be had as follows. Suppose a short horizontal shaft, resting in bearings upon which there is placed a pulley and a gear wheel, the latter having the same pitch diameter as the outside diameter of the pulley. Suppose a belt one inch wide to be laid over the pulley, having a weight of 55 pounds attached to each end. This belt then becomes in the condition of a belt upon pulleys strained to an initial tension of 55 lbs. Now let $27\frac{1}{2}$ pounds weight be taken from one side of the belt and transferred to the other side, when the strain on the belt will become $27\frac{1}{2}$ pounds on one side and $82\frac{1}{2}$ pounds on the other, giving an unbalanced strain of 55 pounds, which we will suppose to be supported or resisted by a pressure of 55 pounds on the teeth of the wheel. Under these circumstances let this whole system be put in motion at such rate that the velocity of the pulley surface and of pitch line of the gear will be 600 ft. per minute. The strain on the tight side of the belt will then be $82\frac{1}{2}$ pounds, while the strain on gear wheel, *which is transmitted*, is 55 pounds, and the force or power transmitted is one horse power, or $600 \times 55 = 33,000$ ft. lbs. per minute. Here the source of power is the adhesion of the belt to the pulley, the belt being strained to $82\frac{1}{2}$ pounds on the tight side and $27\frac{1}{2}$ pounds on the loose side, to secure this adhesion, the $27\frac{1}{2}$ pound tension on the loose side *is employed*. Perhaps less pull on the loose side would answer; how much less can only be found by some experiment. Most mechanics will say that with $27\frac{1}{2}$ pounds pull on the slack side of an inch wide belt it will not "render" or slip on the pulley when $82\frac{1}{2}$ pounds (or 55 pounds more) is loaded on the tight side, but all will admit that at some difference, the pull on the tight side will preponderate over that on the slack side, together with any supposable adhesion. Thus, to transmit 100 pounds, with the initial tension of 55 pounds on both sides, would suppose only 5 pounds strain to be left on the slack side, while 105 pounds would be exerted on the tight side of the belt. Here the belt would certainly fail to hold on the pulley. With the supposed transmission of 55 pounds from a belt strained initially to 55 pounds tension on both sides, and strained when running to $82\frac{1}{2}$ pounds on the tight and $27\frac{1}{2}$ pounds on the loose side of the belt, accurate computation shows, that for 180° contact the value of the coefficient of adhesion is 35 per cent., as set forth in the table.

Careful experiments have proved that belts and pulleys in the condition of workshop practice give a value for this coefficient as high as 0.583; so that a belt initially strained to 55 pounds on both sides will just slip when there is 15.14 pounds on one side and 94.86 pounds on the other, or will not transmit 79.72 pounds.

From the above it will be noticed that the maximum strain on any belt for 180° contact is equal to the initial tension (which may be anything up to the breaking of the belt or its lacing) *plus one-half of the transmitted strain*, whatever that may be; and the load on the bearings and consequent shafting friction is nearly constant whether the belts are transmitting force or not.

There can be no question that Rankine was misinformed when he was told by some practical man that the rough or flesh side of a belt should run next a pulley, and there is also no doubt that the adhesion of a belt is due to close contact and the expulsion of air; but the theory of adhesion consequent to atmospheric pressure will not hold a moment.

At high velocities the adhesion of a film of air to the belt, where entering on the pulley, causes a serious loss of length of arc of contact, while the atmospheric pressure will occasion a somewhat smaller and insignificant gain in length of same arc, where the belt leaves the pulley. These considerations, however, are not important, except at the highest velocities, and their effects have not yet been investigated fully.

But there is another qualification to the effect of belts at high and even moderate rates of speed that imperatively demands application in estimating any tabular statement of the power transmitted by belts at different velocities. Prof. Rankine was the first to notice the effect of the centrifugal tension of a belt. There is exerted upon any belt, at whatever velocity, a centrifugal force, varying directly as the square of the velocity, regardless of diameter of pulleys. Taking the weight of one inch wide leather belting of 7-32ds thickness at 0.0853 lbs. per foot long, it can be estimated that the following will show the results:

Velocity of belt { in ft. per min. }	0	1000	2000	3000	4000	5000
Centrifugal tension { resulting from these } velocities—lbs.	0	0.74	2.9	6.6	11.8	18.4

From this it is evident that within the limits of the table in the manual, from 12 to 28 per cent. of the strain assumed in the manual

as admissible on the tight side of a belt, may be demanded to meet the centrifugal tension. In other words, it does not answer to say that a belt which transmits 1 horse power at a certain velocity is capable of transmitting 8.33 horse power at 8.33 times that velocity.

Whatever may be the merit of the machine tests to manufacturers, the value of the turbine tests, divested from illustration or description of the turbines themselves, cannot have a high estimate. This portion of the work is nearly useless except to the competitors at the Centennial Exhibition and in some instances not especially valuable to the individuals exhibiting.

The second part of the book relates to the history of cotton manufacture in the United States, and is chiefly remarkable for its brevity and for the want of original information. B.

KEY TO THE UNIVERSE, or a New Theory of its Mechanism. Founded upon a I. Continuous orbit propulsion, arising from the velocity of gravity and its consequent aberrations; II. Resisting ethereal medium of variable density, with mathematical demonstrations and tables. By Orson Pratt, Sen. 8vo. Salt Lake City. Pp. 118.

A curious, ingenious and suggestive speculation, developed with a greater knowledge of mathematical principles than is usually shown in works of a like kind. It is, however, far from being a complete solution of the Sphinx's problem, and even the points which are most impressive might have been made still stronger, if the author's reading had been more extensive.

On page 23, the "equatorial ethereal semi-diameter of the sun" is nearly the diameter of Laplace's orbit, in which the centrifugal force of solar rotation would balance the centripetal force of orbital revolution. The distance at which a rotating æthereal atmosphere would have the velocity of light is in the asteroidal belt. The depth of a homogeneous solar æthereal atmosphere is about 207,000,000,000 miles.

On page 26, the statement that the æthereal strata "move in circles, parallel to the equatorial plane and at right angles to the solar axis," is a mere hypothesis. It may be true, or it may not. No evidence is offered, either for or against it.

The same may be said with regard to the statement on p. 31, that "the gravitating force is transmitted with the velocity of light," and

the firm belief "that the heating, magnetic, electric and chemical rays, as well as the rays of different colors, are transmitted with equal velocity." Laplace thought that he had *proved* that the velocity of gravitating action must be at least 100,000,000 times as great as that of light. Professor Lovering has suggested the desirability of extending Laplace's discussion, with the help of the results which have been achieved by modern discovery. Chase has identified the velocity of light with the disturbing velocity at the centre of gravity of the Sun and Jupiter.*

The author's knowledge of the nebula hypothesis appears to be limited to Laplace's presentation of it. He, therefore, falls (p. 73) into the common error of thinking that the notion of the satellites of Mars are at variance with the hypothesis, whereas they lend strong confirmation to Herschel's views of the effect of "Subsidence" in a condensing nebula.

C.

LIST OF PERIODICAL ENGINEERING LITERATURE. Prepared at the Rogers Engineering Library, University of Pennsylvania, by H. Haupt, Jr.

The work throughout gives evidence of careful research in the matter of the statistics of the various periodicals mentioned, which those familiar with this kind of work will appreciate. Some of the most recent periodicals have not been included, owing, we suppose, to the fact that they were issued after the manuscript had gone to the printer. This work is a valuable addition to every library, as it not only gives a list of the titles of engineering periodicals, but in most instances gives the price of the recent journals, both English and American, by which means library companies, ordering or desirous of ordering, periodicals can arrive at an estimate of the cost and know what journals are extant. It is the cheapest work of its kind, and should be possessed by every library.

In reviewing the above-mentioned work, we would note the omission of the Franklin Institute Library from the list of abbreviations, and would remark in defence of the author that this omission was unintentionally made, and was caused by the haste to which the author was subjected.

* Proc. Amer. Phil. Soc.; this JOURNAL, ciii, 285-7.

FRICTION AND LUBRICATION. Prof. R. H. Thurston. Published by Railroad Gazette, New York: 1879. 212 pages, 18mo.

Prof. Thurston has in this book collected veritable experimental data from all the accepted authorities, and has supplemented his information by very thorough experimental results with somewhat novel apparatus at the Stevens Institute of Technology at Hoboken. The question of the nature of friction, its distinctive character when divested from conditions of contact, or associated with them; the question of the continuity of film, and the resistance to molecular mobility of various liquid, or semi-fluid substances under varying conditions of temperature; and the question of resistance to rotation of particles of pulverulent or abraded substances, compressed between solid bodies, are those of frictional resistance in the abstract. And the opening for considering these questions broadly, without limited application, is presented with some force by Prof. Thurston. From this point of view the book becomes an eminently valuable addition to technical knowledge. B.

Franklin Institute.

HALL OF THE INSTITUTE, Nov. 19th, 1879.

The stated meeting was called to order at 8 o'clock P. M., the President, Mr. William P. Tatham, in the chair.

There were present 210 members and 75 visitors.

The minutes of the last meeting were read and approved.

The Actuary presented the minutes of the Board of Managers, and announced that fourteen persons were elected members of the Institute at the last meeting. He also communicated a letter of thanks from the Pennsylvania Museum and School of Industrial Art to the Board, for the use of the class rooms of the Franklin Institute by their pupils, and the liberal arrangements in fitting up the same, which letter was read to the Institute by the Secretary.

The following donations to the Library were reported:

Memoirs of the Geological Survey of India. Vol. 14, and Part 1 Vol. 15.

Do. (Paleontologia Indica) Series 12, Part 1, and Series 4, Part 3.

Records of the Geological Survey of India. Vol. 11, Parts 1—4 Vol. 12, Part 1.

Contents and Index of the First Ten Volumes of the Records of the Survey.

Manual of the Geology of India. By H. B. Medlicott and W. T. Blanford. 2 Vols. From the Geological Survey.

Report of the Commissioner of Education for 1877.

From the Commissioner.

History of the First Locomotives in America. By W. M. Brown. From Lewis S. Ware.

Astronomical Papers prepared for the use of the American Ephemeris and Nautical Almanac. Vol. 1, Part 1. Tables of Eclipses. From Prof. Simon Newcomb.

Computation of Time and Changes of Style in the Calendar. By Spencer Bonsall. Philada. From the Author.

List of Members of the Institution of Civil Engineers. London. From the Institution.

Twenty-third Annual Report of the Board of Trustees of the Water Works to Councils of Cleveland, Ohio. From J. Whitelaw.

Thoughts on our Conceptions of Physical Law. By Prof. F. E. Nipher, Kansas City.

Tornado of April 14, 1879. By J. L. R. Wadsworth and F. E. Nipher.

Report on Magnetic Observations in Missouri, Summer of 1878. By F. E. Nipher. From the Washington University, St. Louis, Mo.

Post Route Maps of Maine, New Hampshire, Vermont, Rhode Island, Massachusetts, Connecticut, New York, Pennsylvania, New Jersey, Delaware, Maryland, District of Columbia, Ohio, Indiana, Illinois, Iowa, Missouri, Michigan, Wisconsin, Minnesota, Texas, Alabama, Mississippi, Arkansas, Indian Territory and Florida.

From W. L. Nicholson, Top. Eng., Washington.

Catalogue and Descriptions of Frederick Krupp's Establishment at Essen, Germany.

Forty-four Detail Sheets of Krupp's Steel Works.

Fifty-nine Photographs of Cannon, Munition Wagons, etc., and Works of F. Krupp in the years 1862, 1873 and 1876.

From Mr. A. G. Buzby, Philadelphia.

Reports of the Secretary of War on the Operations of the Department for the fiscal years ending June, 1877 and 1878. Washington.

From the Secretary.

Report of the International Monetary Conference, held in Paris, Aug., 1878. From the Secretary of State.

Report of the Bureau of Agriculture, Statistics and Mines for 1876. By J. G. Killebrew. Nashville, 1877.

Transactions of the Medical Association of Georgia, 1877 and 1879.

From Dr. W. H. Wahl.

Massachusetts Charitable Mechanics Association. Its Act of Incorporation, etc. From the Association.

Memoirs of the Historical Society of Pennsylvania. Vols. 1 and 7. Collections of the Society. Nos. 1—4 and 6.

From the Historical Society.

Specifications and Drawings of Patents issued from the U. S. Patent Office, May, 1879. From the U. S. Patent Office, Washington.

Hygiene and Medical Reports by Medical Officers of the U. S. Navy. By Joseph B. Parker.

From the Navy Department, Washington.

Instructions to Commanding and Engineer Officers for the Care and Preservation of the Steam-Machinery of Naval Vessels.

From the Bureau of Steam Engineering, Navy Dep't, Washington.

Practical Education. An Address by George Woods. Pittsburg, Pa., 1879.

From Jos. S. Travelli, Pittsburg Western University, Penna.

Annual Reports of the Secretary of Internal Affairs. Part 4, on Railroads, Canals and Telegraphs. 1876—1878.

From the Secretary.

Semi-Centennial Celebration of the Franklin Fire Insurance Co. of Philadelphia, June 25, 1879.

From the Company.

Catalogue of a Collection of Books in all Departments of Literature in the Mercantile Library, Philadelphia. From Lewis S. Ware.

Map of the Tenth Lighthouse District.

From Lighthouse Board, Treasury Department, Washington.

The Woolen Thread. A Lecture by Chas. Vickerman. England.

From the Author.

Chemical Composition and Physical Properties of Steel Rails. By C. B. Dudley. From the Author.

First and Second Reports of the Director of the Meteorological Observatory, New York. From Prof. D. Draper, Director.

American Institute of Architects, Proceedings of the Eleventh and Twelfth Annual Conventions. From the Institute.

Teknisk Tidskrift, Stockholm. Vols. 1-6.

From W. Hoffstedt, Editor.

Transactions of the Royal Irish Academy. Vol. 26, Oct., 1878, and Jan., April, June, 1879. Vol. 27, Feb. and April, 1879. Also, Proceedings. From the Academy.

Æneidea, or Critical, Exegetical and Æsthetical Remarks on the Æneis. By James Henry. Vol. 2. Duplin, 1879.

From the Trustees appointed by the Author.

Die Gasteropoden des Meeres. By R. Hoerners and M. Auinger. Wien, 1879.

Mittheilungen der K. K. Geographischen Gesellschaft in Wien, 1878. From the K. K. Geog. Gesellschaft.

Verhandlungen des Naturhistorisch-Medicinischen Vereins zu Heidelberg. N. S. 2d Vol, Pt. 4. From the Union.

1st, 2d, 25th, 30th to 32d, 36th and 46th Annual Reports of the Royal Cornwall Polytechnic Society.

From the Secretary of the Society.

Eleventh Annual Report of the Department of Marine and Fisheries, being for the fiscal year ended 30th June, 1878. Ottawa, 1879, with Supplements 1 and 2. From the Department.

Specifications and Drawings of Patents issued for June, 1879.

From the U. S. Patent Office.

S. S. Fitch. Six Lectures on the Functions of the Lungs. New York.

M. Sigaud de la Fond. Cabinet de Physique Experimentale. 2 Vols.

Martin and Chambers. Philosophical History and Memoirs of Royal Academy of Sciences at Paris. London.

E. Darwin. Zoonomia; or the Laws of Organic Life. Vol. 1, 3d Ed. London.

L'Abbé Vollet. Leçons de Physique Experimentale. 9th Ed. 6 Vols. Paris.

J. G. Macvicar. Elements of the Economy of Nature. London.

L'Abbé Girard. Synonymes François.

James Hamilton. Observations on the Utility and Administration of Purgative Medicines in Diseases. Philadelphia.

W. Eisenlohr. Lehrbuch der Physik. Stuttgart.

A. Seward. Memoirs of the Life of Darwin. Philadelphia.

W. Jones. Physiological Disquisitions on the Natural Philosophy of the Elements. London.

W. Jones. An Essay on the First Principles of Natural Philosophy. Oxford.

J. B. Biot. Précis Elementaire de Physique Experimentale. 2 Vols. Paris.

J. E. Smith. An Introduction to Physiological and Systematical Botany. Philadelphia.

M. Pouillet. Eléments de Physique Experimentale et de Meteorologie. 3 Vols. Paris. From Mrs. Chas. Ellis, Philadelphia.

Dr. Samuel Chamberlaine read a paper on the "Raising and Reeling of Silk," and remarks were made on the subject by Messrs. Orr and Bingham.

Profs. Houston and Thomson explained and showed the working of their new apparatus for the "Storage of Electricity," which was discussed by Dr. Rogers and Messrs. Scott, Parker and Nystrom.

Mr. William W. Potts described the process of making the artificial stone blocks used for pavements, etc., the materials being crushed limestone and asphalt. Specimens of the blocks, etc., were exhibited.

Col. Henry W. Gray called attention to his invention for electroplating with gold the strings of the piano, and an instrument so constructed was tried.

Mr. Thomas J. Whitney described his "Hot Blast Oil Stoves," which were discussed by Dr. Rogers and Mr. McCollin. Several styles of the stoves were exhibited.

Dr. Carl Seiler explained the construction of his new "Immersion Section Cutter," two forms of it being shown, and entire sections of the larynx, etc., were thrown upon the screen.

Owing to the lateness of the hour, the Secretary's report was omitted, and attention was simply called to a number of interesting things on exhibition.

Mr. Cartwright asked a vote of the members whether the following amendment to the By-Laws should be published or not:

"In case of a vacancy in the office of Treasurer, it shall be the duty of the Board of Managers to appoint a person to perform the duty of the position *pro tempore*."

On motion, the publication was ordered.

Mr. Hector Orr offered resolutions of regret at the death of Mr. John Wise.

On motion, the meeting adjourned.

ISAAC NORRIS, M. D., *Secretary pro tem.*



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